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THE BRITISH JOURNAL OF SURGERY

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CONTENTS OF VOLUME VI.

Number 21.

		PAGE
Introduction		1
Henry Cline (with Portrait)		12
A Case of Contusion of the Axillary Artery	*Lieut.-Col. J. F. Dobson* and *Capt. W. R. Higgins*	15
Bone Growth and Bone Repair (continued)	*Prof. Arthur Keith*	19
Observations on Bladder Injury in Warfare: a Study of 53 Cases	*Col. Andrew Fullerton*	24
Ununited Fractures of the Mandible; their Incidence, Causation, and Treatment	*Percival P. Cole*	57
The Treatment of Gunshot Wounds of the Face accompanied by Extensive Destruction of the Lower Lip and Mandible	*Major V. H. Kazanjian* and *Capt. Harold Burrows*	74
Notes on the Principles and Results of Treatment in 200 Cases of Injuries to the Face and Jaws	*Capts. W. Maxwell Munby, A. Alan Forty,* and *A. D. Shefford*	86
Primary and Delayed Primary Suture of Gunshot Wounds: a Report of Research Work at a Casualty Clearing Station	*Capt. Forbes Fraser and Others*	92
Acute Dilatation of the Stomach	*William Doolin*	125
Notes on a Case of Intestinal Obstruction; with Comments on Bursts of the Intestine	*Rutherford Morison*	135
Rupture of the Small Intestine into the Mesentery, the Result of Indirect Violence of a Missile	*Major Hamilton Drummond*	140
Short Notes of Rare or Obscure Cases	*Various Writers*	144
Reviews and Notices of Books		150

Number 22.

Sir Benjamin Collins Brodie, Bart. (with Medallion Portrait)		157
Bone Growth and Bone Repair (concluded)	*Prof. Arthur Keith*	160
Weight Extension in the Treatment of War Fractures	*Lieut. W. H. Ogilvie*	166
The Diagnosis and Treatment of Injuries to the Crucial Ligaments	*Major S. Alwyn Smith*	176

CONTENTS

		PAGE
Affections of the Large Joints due to Gunshot Wounds; their Late Results and Treatment	*S. W. Daw*	190
Ununited Fractures, with special reference to Gunshot Injuries and the use of Bone Grafting	*Ernest W. Hey Groves*	203
The Treatment of Disabilities of the Upper Extremity in Military Surgery	*Major Naughton Dunn*	248
The Results of Primary Excision for Wounds of the Elbow-Joint	*Capt. A. Eisdell Moore*	265
The Structure, Forms, and Conditions of the Ends of Divided Nerves	*Major Edred M. Corner*	273
Injuries of the Peripheral Nerves from the Surgical Standpoint	*Major H. S. Souttar and Capt. E. W. Twining*	279
Suture of the Musculospiral Nerve; 3 Cases	*Capt. Gwynne Williams*	315
Some Notes on Operative Procedure in Nerve Injuries	*Robert Kennedy*	317
Short Notes of Rare or Obscure Cases	*Various Writers*	324
Reviews and Notices of Books		328

Number 23.

Robert Liston (with Portrait)		333
On Cancer of the Tongue (Bradshaw Lecture, 1918)	*D'Arcy Power*	336
Treatment of Cases of Fractured Femur at a Base Hospital in France	*Lieut.-Col. Victor Hurley* and *Major S. H. Weedon*	351
The Operative Treatment of Ruptured Internal Lateral Ligament of the Knee	*Capt. T. P. McMurray*	377
A Procedure for Avoiding Colostomy and Colectomy	*A. Rendle Short*	382
Displacement of the Mandibular Meniscus and its Treatment	*J. Hogarth Pringle*	385
Secondary Jejunal and Gastro-jejunal Ulceration	*Garnett Wright*	390
Some Phenomena of Surgical Shock	*A. Rendle Short*	402
A New System of Localization and Extraction of Foreign Bodies in the Brain: a Preliminary Note	*Capt. J. Newbery Fergusson*	409
A Study of a Series of Peripheral Nerve Injuries from a Surgical Aspect	*Brevet-Major J. L. Joyce*	418
Fracture of the Femur: a Method of Holding the Fragments in Difficult Cases	*Capt. Dennis W. Crile*	458
The Recognition and Significance of Fractures of the Patellar Border	*Capt. R. W. A. Salmond*	463
Short Notes of Rare or Obscure Cases	*Various Writers*	466
Reviews and Notices of Books		470

Number 24.

PAGE

Sir William Fergusson (with Portrait) 479

The Pathology of Gunshot Wounds of the Spine and Spinal Cord
Col. William Thorburn and *Major George Richardson* 481

Restoration of the Urethra by means of Baer's Membrane
Capt. Joseph E. Adams 494

The Treatment of Functional Disability of the Limbs in a Special Military Surgical Hospital *Lieut. Wm. Cuthbert Morton* 497

Digestion of the Œsophagus as a Cause of Post-Operative Hæmatemesis
J. Hogarth Pringle and *John H. Teacher* 523

Bones showing the Effects of Gunshot Injuries, in the Army Medical Collection
Prof. Arthur Keith and *Capt. Morton E. Hall* 537

A New Method of Treatment for Suppurative Arthritis of the Knee-joint
Major J. Everidge 566

War Contractures—Localized Tetanus, Reflex Disorder, or Hysteria
Lieut.-Col. A. F. Hurst 579

Reviews and Notices of Books 606

GENERAL INDEX TO VOLUME VI.

THE
BRITISH JOURNAL OF SURGERY

INTRODUCTORY.

A REVIEW of the work of surgeons during the past momentous four years of military service, and its relation to the future of the practice of surgery, is a gigantic undertaking little suited to a short introduction to the sixth volume of the BRITISH JOURNAL OF SURGERY, while so little are we in a position to grasp or even conceive the actual conditions under which we shall live and work when the blessings of peace are again vouchsafed to us, that a forecast can provide but speculative interest. Yet it may not be unprofitable at this juncture to take stock of a few of the conditions which exist at the moment, and to ponder upon the influence these may possibly exert on the practice of surgery and the life and position of the surgeon in the future.

The great outstanding features of military surgery lie in the possibilities which are provided by the casualties of battle for the rapid accumulation of facts and experience in a special field, and in the wide distribution of this work amongst a large number of medical men to whom under ordinary conditions the active practice of surgery might have been restricted in many instances to the narrowest limits, or even avoided with studious precaution.

These conditions have permitted a combination of men representing every branch of medicine to join in collaborative research of a character and extent which ordinary circumstances could never have allowed, and effected a general assimilation of thought and aim difficult to conceive under the comparatively water-tight-compartment arrangements which exist in times of peace. Yet, side by side with the general breadth of outlook which has been thereby in great measure attained, a tendency to an undesirable degree of specialism has sprung into existence. It is to a consideration of these features that the following cursory remarks will be confined, and of the question as to how far they promise to exert an enduring influence on individuals who have been suddenly translated from a strenuous or an easy-going life, and whose energies under the conditions of the previous fifty years might have been confined to a narrower sphere and expended perhaps on an inglorious routine broken only by an occasional holiday or attendance at a medical meeting.

A glance may first be taken at the material resources in medical personnel at the disposal of the War Department. The officers available may be conveniently grouped as follows: (1) *Newly-qualified men, and qualified men who found themselves unattached and free at the outbreak of war;* (2) *Settled general practitioners;* (3) *Consulting physicians and surgeons, specialists in the various departments of medicine;* and (4) *Workers in pure science.*

1. The first group—consisting of volunteers, fresh young minds abounding in energy and the desire to win their spurs on their simultaneous entry into the arena of active life and into the field of military service—has afforded a most useful asset. As a class, a little over-anxious perhaps, to wield the knife, or to join the forefront of battle—where many, alas, have laid down their lives or become permanently handicapped for

the future. The unattached, often a globe-trotter, has brought knowledge of men and of life under the conditions of distant climes which has often rendered him useful under circumstances totally unfamiliar to the newly-fledged surgeon. The value of such an assemblage of plastic material to the regular service can hardly be overestimated. On the other hand, no single body of men has derived more benefit from its association with the war. Habits of discipline, opportunity for estimation of their own powers and capability, medical and surgical experience, and even material improvement in personal health and strength, have been acquired as a result of military service.

2. The general practitioner, as representing the actual body of the profession, has proved himself the strength and corner-stone of the medical service. Habituated to onerous and regular work, an experienced student of human nature, and accustomed to deal with emergencies of every kind, he has thrown himself into the great work of the service with an energy and carelessness of self which is beyond all praise. Many of them, moreover, brought not only medical skill and experience, but also administrative capacity, developed as a result of prescient patriotic service with the Territorial Force, a virtue which has been but too inadequately recognized and repaid. Yet this group of men also has gained some advantages which civil practice could not afford, such as a change of life, and the not infrequent possibility of devoting themselves to particular lines of work specially germane to their tastes and capacities: small recompense, perhaps, for a virtually abandoned practice, and for the constantly recurring thoughts of the trials and troubles inflicted on those left at home or in the temporary shelter which the Territorial officer's means have allowed him to provide for those nearest and dearest to him.

3. The consultant physician and surgeon, a class to which a defined position had already been allotted in foreign armies, entered the Service under such indefinite conditions as can never again occur. It seems incredible that no actual scheme of duties should have been assigned to the consultant in the reorganization of the Medical Service which followed the South African War: prospective duties of which so broad an outline has been sketched by the late Director-General of the Army Medical Service in the pages of this journal *:—

> They set the scope and standard of practical work and scientific investigation. The Administration relies on them for the fixing of surgical policy. The responsibilities of these officers are great; their efficiency is proportional to *their own* appreciation of their powers. They determine whether the means at the disposal of the hospital surgeons are adequate or not. They supervise the operations and approve the operators, so that upon them depends whether or not all that is best in British surgery is available for the soldier. . . . Nothing less than the almost complete transference of responsibility for the surgery of the war to special officers can satisfy the conditions.

None the less, it remained for the consultant officer at the commencement of the war to feel his way into the position, although cordially and heartily helped by those in authority, both at the War Office and in the field.

Never before has the specialist played such a prominent part in the field of war, neither could the train of inconsistencies which has attended his utilization have been foreseen. On the one hand, those to whom work of a general character happened to be assigned were often anxious to develop special departments galore; while, on the other hand, some of those restricted to the performance of the work of their own choice craved for a wider sphere of action. The latter is perhaps readily intelligible, for the joy of emancipation, when the opportunity of engaging in more general work offers, to the man whose time may be divided between operating for adenoid vegetations and chipping away fragments of the mastoid bone, or to the ophthalmologist whose main duties may consist in removing damaged eyeballs or determining errors of refraction, can be easily conceived. Even the gynæcologist, with his ever increasing operative opportunities in civil life, has been not unwilling to devote his operative skill and energies to another sex

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and a wider territory on the human frame. Let it be said, however, that no recruits to the field of general surgery have more amply justified their ambitions, or more readily fallen in with the exigencies of the situation, than the specialists.

4. Lastly, we have the man of pure science—the physiologist, the pathologist, or the philosopher. The position of these workers has been unique: never before have they met the practising doctor in such broad and intimate association, with corresponding opportunities of disseminating their knowledge, of utilizing its practical application, and of inducing habits of thought and reflection in the mass of the profession.

Let us now turn to a cursory consideration of the work that has had to be undertaken. The subject of administration has been dealt with in these pages in the paper already referred to. It suffices, therefore, to make the bald statement that without good administration good surgery is an impossibility. At the same time the two are interdependent, since the methods and devices of the surgeon may determine great administrative issues, such as questions of transport of the wounded, or the possibility of rapid return of men to their units in the line. The surgeon may fairly claim to have done much to solve many knotty problems in this direction, and to have well fulfilled his share of duties of enormous importance to the efficiency of the fighting machine.

It is notorious that medical staff work, and the administration of medical units, have been carried out with conspicuous success during the entire course of the campaign. For this result the country is indebted to the officers of the Royal Army Medical Corps, who have abundantly justified the efficient prospective preparation and training instituted and maintained during the years subsequent to the reorganization which followed the South African War. In the matter of medical units, however, it has been a striking object lesson to observe the efficiency with which many have been organized and administered by civilian practitioners, the majority composed of men who had previously undergone training in the Territorial Royal Army Medical Corps. Many of these latter, indeed, have administered their units in as faultless a manner as the best regular officer: exhibiting capacity for organization, the faculty of ready improvisation, and power to meet unexpected difficulties, which has excited the greatest admiration and respect from their civilian brethren. Beyond these previously trained officers, the practical experience of war has developed the faculty of military hospital administration in not a few purely civilian practitioners to whom the subject had been hitherto absolutely unfamiliar, and many of these also have proved themselves second to none.

The aptitude for administrative duties, and indeed the earnest desire to undertake them, has been a somewhat unexpected revelation in the ranks of the civil profession. The phenomenon may be put down in part to the sense of relief engendered in many men by a change of daily routine; in part, perhaps, to the satisfaction of assuming duties the regulations for which have been set down with such exactitude that it is possible to carry them out without error or undue worry; or, again, to the fact that to a certain number of men a position which entails the personal control of others always makes an appeal. Moreover, this craving for administrative power has not been confined to any particular group of the men engaged, but is met with amongst all classes.

Before proceeding to a brief review of the nature and results of the surgical work actually performed, it may be worth while to inquire how far either the civil or the military surgeon was prepared to undertake successfully the treatment of gunshot injuries of the nature they have been called upon to deal with.

The sequence of events in this matter has assumed an oft-repeated type. The most modern observations in military surgery on which reliance was placed related almost solely to wounds inflicted by bullets of small calibre of a particular kind. The nature of these wounds was well understood, as also their comparatively innocuous character, provided the soft parts of the body alone were affected. This knowledge was founded on direct observations made on wounded men; and the variations likely to accrue from the

altered ballistic qualities of the pointed bullet had been foreshadowed both by experimental investigation and the limited experience gained from the Russo-Japanese and Balkan Wars. The expectation of having to deal with wounds of limited extent, prone to heal spontaneously without any active surgical aid, consequently dominated the views of the military surgeon at the commencement of the campaign.

It cannot be said that experience regarding the primary nature and subsequent course taken by wounds caused by bullets of small calibre has in any way deviated from that observed in previous wars, except in the one important particular that more frequent irregular impact of the pointed bullet has occasioned the occurrence of a larger proportion of wounds in which the degree and extent of contusion of tissue is increased.

Our preliminary deficiencies lay in the fact that we allowed it to be necessary to rediscover for ourselves what our grandfathers and great-grandfathers could have taught us: the terrible nature of injuries produced by fragments of shells and bombs—characterized at the present day by a still greater degree of destruction of tissue as a result of the introduction of high explosives. We were well aware that wounds caused by bullets of small calibre healed easily, but we also knew "that shell wounds, with the exception of tracks caused by clean leaden shrapnel balls, always suppurated," in spite of the fact that patients suffering from either shell or bullet wounds might be exposed to identical conditions and surroundings.* Our shortcoming lay in the fact that we appreciated neither the number of shell wounds we should have to deal with, nor their gravity and extent.

The second problem that awaited us was the suitable application of the principles of wound treatment. Better instructed than our forefathers as to the actual causes of the accidents and complications which may interfere with the physiological process of reparation, in civil surgery we had developed a system, on the groundwork of the principles laid down by Pasteur and Lister, by which wound infection is avoided and reliance placed solely on the natural processes of the body.

It may be fairly claimed that in civil practice the aseptic system has ensured better average results than had ever before been attained, and upon this system, with certain minor antiseptic additions, the military surgeon proposed to rely. The gross nature of the infections met with, however, led in the first instance to failure in the methods employed, although time has shown that the failure was really the result of their imperfect application. Primary failure was followed by an eager grasping at chemical antiseptic media, employed with the object of retarding, controlling, or arresting the progress of the process of infection. A fresh evolution of successive steps commenced, ending in a definite separation of the methods of dealing with infected and non-infected wounds respectively, and in renewed reliance on the normal process of spontaneous repair, together with a conviction that chemical media deal only with organisms developing on the surface of the wound. Further, that infection of the tissues can be best arrested by mechanical removal of the infected area, adding as precautionary measures excision of devitalized tissue capable of forming a suitable nidus for bacterial growth, and such arrangement of the wound as will prevent retention of body fluids likely to form a favourable culture medium.

Thus, as the outcome of patient effort, a rational standpoint has been attained, and certain definite conclusions arrived at: (1) That effective primary disinfection of a gunshot wound should be mechanical in nature, and that if this procedure be radical, such a wound (provided that treatment be undertaken sufficiently early and amidst satisfactory surroundings) may be closed as safely as a wound entailed by a surgical operation. (2) That in view of the many difficulties which may accompany military surgery, primary closure of the wound is often better replaced by the so-called delayed method, i.e., closure at the end of three or four days. (3) That attainment of a sterile surface, and subsequent closure of primarily infected wounds, may be promoted and hastened by the employment

* MAKINS, *Surgical Experiences in South Africa*, first edition, p. 486.

of suitable antiseptic media; also, that the antiseptic method is particularly valuable as a means of ensuring the possibility of early secondary closure of granulating wounds —the type of closure applicable to gunshot injuries in almost any circumstances, and hence the most valuable of all.

Passing from the subject of general principles, it may be asked how far the surgery of the future is likely to be influenced by the enormous experience gained in the treatment of gunshot injuries.

A deeper and more practical interest has been taken in such matters as the nature and treatment of shock and hæmorrhage, and attempts to deal with these conditions by intravenous administration of drugs and by the transfusion of blood have been undertaken on a scale far beyond anything that has been practicable before. These methods, although still in the balance, have received strenuous support from many quarters, and it is reasonable to assume that progress has been made.

The treatment of compound fractures has occupied a very prominent position. The observation of a large accumulation of imperfect results obtained in the surgery of war has only confirmed the unsatisfactory experience as to interference with function which had been already acquired when opportunity was taken to examine the ultimate results of fractures in general amongst any large body of men, such as the police force. Here, as in so many other directions, the urgent need for national economy—in the most important direction for the future of the empire, economy in man-power—has deeply and favourably influenced surgical practice, and realization of the importance, not only of returning men to the line, but also of conserving useful if not physically perfect citizens, has been more and more impressed upon surgeon and administrator alike. There can be no doubt that methods of transport, of discriminating primary treatment of the wound, of immobilization, and of rational after-treatment, have received an impetus which will exert a permanent influence on the surgery of the future.

Wounds of the great articulations constituted a perplexing problem; but while the power of the synovial membrane to deal spontaneously with infection has been more generally recognized, and has resulted in more rational views as to primary closure of the joint cavity; and, in the case of suppurating joints, in dealing when possible with the cavity of the articulation—that is to say, a well-bounded space—before the extra-articular structures are involved in the infection, the general lines of treatment have only been brought into consonance with those which have guided the civil surgeon for many years. Again, experience gained of the results of primary and secondary excisions of the joints has been but a repetition of that of the civil surgeon in the treatment of infected joints met with in connection with injuries, acute infections of the bones, or in tuberculous disease. A disposition to resort freely to excision has been followed by a reaction in favour of expectant methods, imposed by observation of the ultimate results of the more radical procedure.

Extended observation of methods of treating wounds of the large blood-vessels and their after-consequences, has led to increasing confidence in a more active attitude in either the early or later stages, and to a more general development of operative technique in the attempt to effect repair rather than to proceed at once to occlusion of a main trunk. Ideal results, however, can hardly be said to be common, since ultimate thrombosis of sutured vessels has occurred in a considerable proportion of instances, and it still remains doubtful how far improvement in technique will obviate this disappointing termination, when dealing with the contused injuries resulting from gunfire. One great principle of pre-war surgery has been practically reversed, as evidence has been furnished that simultaneous ligature of the satellite vein accompanying a large artery is to be preferred to that of the artery alone. Again, the adaptation by Tuffier of Carrel's method of temporarily maintaining the circulation in a divided artery by the introduction of a junction tube between the separated ends, in order to gain time for a gradual increase of the collateral circulation, will form a permanent addition to the resources of the surgeon.

Active intervention in injuries of the central organs of the nervous system has been enriched by the introduction of many technical details, but little change in general principles has been evolved. The main subject of argument and contention has consisted in determining the most suitable moment for intervention by the surgeon. The chief gain in this field has been furnished by the labours of the neurologist, which have resulted in an increase of knowledge which must prove of the utmost value in the future both in the investigation of disease and in regulating the intervention of the surgeon. Knowledge of symptomatology, and of the indications for immediate or late treatment of injuries to the peripheral and sympathetic nerves, is steadily increasing, and in this field a permanent advance seems fully assured.

Perhaps the most far-reaching development is that met with in the treatment of injuries involving the thoracic cavity. It is of interest to recall the grounds upon which this has been evolved. First, upon observation of the favourable course taken in a certain proportion of the gross injuries in which the cavity of the thorax had been laid open, and the conviction gained that the more frequent fatal issues depended upon consequent infection of the cavity rather than upon the primary gravity of the traumatism. Secondly, upon confirmation of the views, so ably put forth by Macewen, that artificial arrangements for the maintenance of respiration are unnecessary in dealing with the opened thoracic cavity. Although the rules guiding intervention in cases of injury to the chest may still require some regularization, the experience gained of the value of operative measures in properly selected cases, and the safety with which they may be carried out, prove that a large field has been opened up to the civil surgeon in the future.

One of the most striking triumphs attained, the establishment of an active, in place of an expectant, attitude in the presence of injuries to the hollow abdominal viscera, will hardly affect the future of abdominal surgery beyond the confines of military service; it is a triumph of the military surgeon over prejudice and the former imperfect application of rules that had long guided the civilian practitioner; but for the wounded soldier the change of view which has been attained must be regarded as an inestimable boon.

The general conclusion which is to be drawn from the results obtained is mainly to the effect that military and civilian practice have been drawn into closer conformity. The false but widely enough entertained view that there is something special in gunshot wounds, and that they require a surgery of their own—beyond the facts that tissue destruction is great, that a great proportion are grossly dirty, and that the surroundings and equipment may be in some cases totally unsuitable for operative intervention—has been proved to be incorrect.

This brief review of the probable general effects of the surgery of the present campaign on military and civil practice, leads up to another important issue which has been brought to the forefront by the administration of the Medical Service of the War. This question cannot be better introduced than by a quotation from the Introduction to the fourth volume of this Journal, on "Surgical Organization in War" * :—

> If we cast our regards around us, we find a tendency more and more to classify the wounded into groups, demanding experts in special branches of knowledge for each class. This is inevitable, and suggestive of changes in the future. The system has not been in the first place designed, nor established of set purpose. It has evolved, and the advantages are so apparent that it has been encouraged . . . Its educative value is enormous, and it offers unique opportunities for research. Unlike many other tendencies, there are no administrative objections to it, and it can be suffered to grow and flourish without the production of a narrow specialism.

It may be at once agreed "that there are no administrative objections to the system," and we may go further and assert that administrative considerations are those which have carried the main weight in its introduction, in much the same way that financial

* *Loc. cit.* p. 7.

considerations bear a far from insignificant part in furthering the growing tendency of late years to the increase of specialism in civil practice.

To a limited extent specialism is rational and inevitable. This has been fully recognized in specialities which demand particularly fine technical detail, such as the surgery of the eye, the ear, or the throat. Methods of investigation and meticulous operative technique, demanding prolonged training, and capable of utilizing an enormous field for practical exercise, have justified and indeed rendered necessary the establishment of these departments in medicine, and even of hospitals devoted solely to their particular objects. The segregation of the patients in special hospitals, however, is purely a question of administration and convenience, and not the outcome of actual medical or surgical requirements; moreover, such hospitals are supplemented by special departments in the general hospitals which the general surgeon and specialist alike would see relinquished with regret. Specialism in these directions must be regarded not only as an advantage, but also as a necessity; but if the specialist is to retain his highest degree of efficiency and utility, his relation with his colleagues in general medicine and surgery cannot be too intimate, and it is undeniable that the broader the general culture the specialist possesses the greater will be his efficiency even in his chosen department.

The specialism born of military administration stands on a far different basis, and in the interests of the surgery of injuries it will be nothing less than deplorable if, for the future, diseases and injuries are to be classified into groups demanding experts in special branches of knowledge for each class. We may first note the natural result, dependent upon the common tendency of human nature. The surgeon who does not expect to be called upon to treat any particular disease or injury loses interest in the subject, and becomes either less capable, or incompetent, to deal with it; hence his breadth of view and general efficiency tend to narrow in every direction in which a new so-called speciality is set up. The specialist himself is liable to become still more restricted in outlook, unless he be a man of unusual energy and determination. Limitation to a narrow field, while it may provide the opportunity for the development of technical facility, on the other hand obstructs the entrance of the many sidelights which may illuminate the special province if the surgeon be engaged in general work at the same time.

The history of surgery shows clearly enough that if the science is to continue to progress and develop on broad and comprehensive lines, the advance must be the result of the efforts of the general surgeon, and not of men whose energies are directed and views confined solely to one small area of the human frame. To whom for instance are we indebted for the evolution of the true principles of wound treatment? To Hunter and to Lister, men whose sympathies extended over the widest area. Note the catholicity of Astley Cooper, although his name is now principally remembered by his special work on fractures and dislocations. The surgery of the stomach owes its genesis to Billroth; that of injuries of the intestines to A. Cooper and J. Croft; that of the kidney to Morris and Lucas; that of the central nervous system to Macewen and Horsley; ovariotomy—the precursor of the later triumphs of abdominal surgery—to Spencer Wells; the plastic surgery of the palate to W. Fergusson: all general surgeons in the proper sense of the term. A mere glance at these names raises another aspect of the question; a general surgeon who shows aptitude in dealing with any special class of case becomes in a sense a specialist in spite of himself; either in hospital work or in private practice he will have little choice but to deal with the class of disease which his fellow practitioners see fit to send to him. This form of specialism should suffice, and may indeed represent the ideal from the point of view of the patient, although it may by no means always meet with the same sympathy and content on the part of the surgeon concerned.

The tendency to develop specialism on military lines is of a far more stringent character. We find a specialist for the treatment of fractured jaws; another for fractures of the thigh; and, strange inconsistency, we meet with a third department, that of orthopædics—for which a special course of a few months in some instances suffices to qualify—claiming almost the whole field of the surgery of injuries. From an adminis-

trative point of view in dealing with the huge accumulation of the casualties of war, the convenience of such a system may be allowed, as also that it has been attended with a considerable measure of success, and benefit to the soldier. On the other hand, when the peculiar conditions of war are ended, the segregation of patients scattered over the entire United Kingdom to such a degree is impracticable; therefore, while the experience gained by the system may be of value, its continuance is undesirable as well from the administrative as other points of view. Come what may, the great mass of the population must be cared for by the local surgeon and general practitioner: and the proper policy of the future is to enlarge the opportunities open to these men of obtaining experience, and to provide them with ample means and facilities for carrying out any form of treatment, and not to seek to limit their range of thought and action.

In centres of medical education, the segregation of various classes of case in separate wards may be useful for purposes of instruction, but this should not require also the appointment of a specialist in the narrow sense of the term. Every general surgeon has special aptitudes and predilections, as has been abundantly shown in the past, and it is in this direction that special instruction should be sought for and provided. Individual surgeons may vary in their ability to perform faultlessly any particular operation; but this in no way affects the more important questions of scientific knowledge and insight, and of their capability of making advances in the investigation or elucidation of problems raised by the disease or injury for which the operation may be needed. Is it possible to imagine a school which is to produce the ideal physician or surgeon presided over by a collection of specialists? For the future of surgical science no less than for the dignity of the profession, let the professor remain a surgeon, and not descend to the position of a stomatologist, a urologist, or a proctologist.

To pass from the vexed question of specialism, we may next briefly consider what is likely to be the effect of military life and experience on the individual surgeon, and on the surgical calling as a whole. Certain influences must be wholly to the good, others may be regarded as uncertain in their ultimate effect.

The first and one of the most important is the intimate connection which has been established between workers in pure science and in the practice of surgery. The man of science has been living under the same roof and under the same conditions as the surgeon, and both socially and professionally an intimacy of relation has obtained such as has never previously existed between them. Never before have the physiologist and the pathologist come into such close contact either with the practitioner or the patient—with the result, it may be ventured to say, of humanizing the man of science, and at the same time of allowing the practitioner to drink more freely and intelligently of the stream of knowledge which the laboratory worker is in a position to pour out. By an unexpected course of events, consequent on the special nature of the warfare, the hospital ward has become the chief department in the laboratory of the man of science, and the surgeon his main collaborator. The chief source of difficulty in ensuring the most useful lines of work experienced in laboratories unattached to institutions for treatment of the sick has thus been eliminated. The scientist has been able to observe the direct results of the adoption of his recommendations, while the surgeon has not had blindly and submissively to put in practice methods as to the evolution of which he has been more or less ignorant. These circumstances afford an illustration of a method of broadening surgical views in singular contrast to the trammels imposed by recourse to specialization in the treatment of each form of disease. This close association of pure science and surgery is one of the features of recent military work the persistence of which in times of peace is to be most earnestly desired and looked forward to, as likely to open up the path of progress in the future.

Other instances of the establishment of a closer relationship are not wanting, as, for instance, that of the consulting physician and surgeon. It cannot be denied that in many cases the long-existing relationship between these two great branches of the profession has

become of late years somewhat less intimate, principally perhaps as a result of a feeling on the part of the surgeon that the physician was not always in sympathy with some of the more active methods of modern surgical treatment of disease. The entrance of the consulting physician into the domain of military work has done much to correct this feeling, and in fact in some fields the physician has proved even more active in his views than his surgical colleague.

The consultant has never enjoyed a better opportunity of appreciating the breadth of knowledge of medicine and of human nature possessed by the general practitioner, or of seeing illustrated the mutual understanding which should exist between doctor and patient. Under no circumstances can the bond of sympathy be greater than that which exists between the wounded soldier and the surgeon on active service, since they are brothers indeed, striving side by side for the same object and under the same conditions of life. The countryman has perhaps seen a truer picture of the consultant, separated from the normal surroundings of either hospital or social life, and has found him a man of simple tastes enough, and not unwilling to put his hand to duties which a dresser might shirk if possible. Even the almost comic rearrangement of the professional standing of the older and younger men, much irritation as it sometimes occasions, may not have been in all ways a disadvantage: seniors have revived their recollections of their own junior life, and the teacher his own ways when a pupil, while wearied minds have been spurred and stimulated by contact with the young and fresh.

In fact, the general intermingling on common ground and under identical conditions of every branch and grade of the profession can hardly have failed to establish a better mutual understanding and a closing up of the ranks which should have a persisting influence on the body politic, and lead to an increase of its importance and dignity in the community.

The influence of this long period of military service upon the individual surgeon, on his aspirations, his mode of life, and his future destiny, is harder to appreciate or forecast. The settled practitioner, removed either voluntarily or compulsorily from his normal surroundings, has been living through a "sort of interval between the parts" on the stage of life, his whole aims and ambitions interrupted, and placed under conditions in which the common responsibilities of life are either diminished to a negligible degree or have vanished completely. The period of suspension has been indefinite, the duties often far different from those for the fulfilment of which his scheme of life had been planned. To some has come the happy chance of merely shuffling off uncongenial shackles of existence: some have become engaged in work far more congenial to them than that they left; others are constrained to perform duties for which they have no liking and feel ill-adapted; while practically all enjoy that strange sense of ease accompanying diminished personal responsibility, and inseparable from the unfamiliar despotism implied by the magic word discipline, under the influence of which their lives are now being passed. The kaleidoscopic re-arrangement of the whole profession which must result when normal conditions return can hardly be foreseen, but a few words may be devoted to the possible influences which may specially affect the practitioner of surgery.

On the professed surgeon these will be slight, except in the favourable effect likely to follow a break in routine, the freshening of thought and ambition, and an increase in general breadth of view. The more important problem will arise in the case of those who up to the advent of their period of military service either entertained no surgical ambitions, or foresaw no opportunity of realizing them; or, again, in those at whose feet opportunities have fallen at the very threshold of their career which might have dazzled even the experienced surgeon. We may safely assume that with the advent of peace a large proportion of the men of either of these classes will yearn to continue the surgical practice in which they have been engaged during the war.

Certain conditions calculated to make this the more easy will probably be found, such as the wide development of more or less well-equipped voluntary hospital units unwilling to suddenly cease their activities; the fact that it will be long before the surgical flotsam and jetsam of war has been finally disposed of; and, again, the circumstance that

the surgeon will return with a reputation of having been actively engaged in a field of surgery offering great opportunities and a very wide scope of activity.

It may be asked how far experience gained in the field will have fitted its possessors to engage in similar work under the conditions obtaining in normal civil life. To some of these the interest will be in surgery as a science: to some it may mean no more than the capability and opportunity to undertake operative work. However pure may be the aspirations of the surgeon, it cannot be gainsaid that the operative side of surgery instinctively appeals to most of its students and practitioners, and to some it constitutes the whole end and aim. The power of relieving mind and body; the possibility of eradicating disease or repairing injury; the relations which a successful operation may establish between surgeon and patient; the knowledge of the pathology of disease which may be obtained by the opportunity of investigation during life; and lastly, the material gain which may accrue to the surgeon himself: all combine to render operative surgery a fascinating department of medicine—but also to emphasize the necessity of maintaining a proper perspective in the use of the knife. While no doubt can exist that the foundations of many successful surgical careers have been laid, and that strictly surgical work will be more widely distributed than in the past, yet the path to surgical practice in time of peace and under normal conditions may not be so smooth and easy as it has appeared when distantly contemplated during the quiet intervals which the military surgeon enjoys between the times of stress.

Military service indeed, while of the highest value, yet fails to supply much of the training and experience required for success in the practice of surgery. In the first place, the field is limited in many directions. The patients for the most part are young and healthy men; their injuries are of a class but rarely met with in ordinary life, and their treatment is undertaken under very special circumstances. The military surgeon works under conditions very unlike those of peace. Putting aside the bond of mutual sympathy which life in the field does so much to encourage, the intangible and far-reaching influence of military discipline enters into every issue. A soldier is not his own, his every act is conditional on the will of his superior officer, and consent on the part of the wounded man to any course recommended by the surgeon is accepted unhesitatingly in a like spirit. Such self-abnegation might be thought impossible; but a strange feature of human nature surges to the front and makes it far easier to understand than might be imagined, even bearing in mind that the soldier appears to think an operation the only form of treatment that can put him right. His willingness to submit himself depends upon the same relief experienced in escaping from the exercise of personal responsibility which permits him to be happy and contented in the field although torn from his home and normal surroundings, and which passes with him from active duty to the wards of the hospital. How far this characteristic may persist amongst old comrades in the army it is difficult to say, but even if the patient remains equally docile, this will not eliminate the influence of anxious friends upon the surgeon's mind, and questions of treatment will not be so easy of determination as at a casualty clearing station or a hospital on the lines of communication. It must be appreciated, too, that the work in military hospitals in time of war is done in a surgical atmosphere; the surgeon is free from all distractions of professional worry or social engagements; it is rare that serious work must be undertaken except in close association with others similarly employed: and there is little chance of the sight of the future village cripple troubling the walks abroad of a Charles Bovary.

The last remark brings into prominence one of the most unsatisfactory features of military surgery from the educational point of view—the impracticability of following cases to their ultimate issue, and in a great majority of cases the impossibility of observing more than a limited stage of the treatment of any particular form of injury. Even in face of the prolonged period that war has persisted, this disappointing feature has not been eliminated, although great pains have been taken to attempt to obtain continuous histories by a system of correspondence, and efforts have been made to allow surgeons from the front line to make visits to the hospitals on the line of com-

munication. Continuous observation of the course of individual cases has, however, been impracticable, and this has been a serious disappointment for the surgeons concerned. The consulting surgeon and the medical meeting have played important parts in this direction, but even here the arrangement by which the consulting surgeons work on parallel instead of radiating lines has done much to modify the advantages that might have been derived from their presence. In their respective areas the consultants have done much in regularizing and diffusing knowledge, for it is remarkable that the same odd disinclination of men belonging to neighbouring units to visit each other is found in military hospitals in the field as in a town at home. Our colonial and American colleagues have also done much to break in upon this spirit of aloofness, as well as to stimulate our energies in many directions.

Near or distant as may be the happy moment to which we all look forward, now is the time for meditation, and for the formation of plans of life; and if this desultory table-talk serves to quicken reflection, it will not have been set down in vain. Fortunate are those who during this period of storm and stress have been able to decide upon the life they hope to lead; and to none is a more useful prospect likely to be opened up than to members of our calling.

GEORGE H. MAKINS.

HENRY CLINE.

1750—1827.

The Cline bequest, after the lapse of three generations, has at last come into the possession of the Royal College of Surgeons of England, in the form of French Rentes. It is a direct reminder of the French Revolution, and of the views held by a distinguished contemporary English surgeon in regard to that great upheaval.

Henry Cline was born in London on March 25, 1750, and was educated at Merchant Taylors' School, in Suffolk Lane, which he entered in 1759, the headmaster being John Crichc, who was soon afterwards succeeded by James Townley, the author of *High Life below Stairs*. In August, 1767, Cline was apprenticed to Mr. Thomas Smith, one of the surgeons to St. Thomas's Hospital, for the statutable period of seven years. This apprenticeship not only entitled him to his master's teaching, but it allowed him to attend as a pupil at the hospital, and gave him a claim to a surgical post at St. Thomas' hospital in the event of a vacancy. The position of surgeon depended nominally upon the vote of the whole body of governors ; in reality the only competitors were the hospital pupils who had served their apprenticeship to the surgeons. Cline made such good use of his opportunities that he frequently lectured upon anatomy to his fellow students before he was out of his indentures, taking the place of Joseph Else, the appointed Lecturer in the School. On June 2, 1774, he was admitted a member of the Surgeons' Company—the successor of the United Company of Barbers and Surgeons, the immediate predecessor of the College of Surgeons of England. In this year he says : " I had the happiness of hearing the first course of lectures which John Hunter delivered. I had been at that time for some years in the profession, and was tolerably well acquainted with the opinions held by surgeons most distinguished for their talents, then residing in the metropolis ; but having heard Mr. Hunter's lectures on the subject of disease, I found them so far superior to everything I had conceived or heard before, that there seemed no comparison between the great mind of the man who delivered them and all the individuals, whether ancient or modern, who had gone before him." This is a remarkable testimony to the influence of Hunter's teaching upon the more receptive minds of a younger generation, trained in the older school of surgery, but ready to advance upon the new road shown them by our great master.

In 1775 Cline married Miss Webb, and took a house in Devonshire Street, E.C., moving a few years later to Jeffries' Square, St. Mary Axe. Joseph Else died in 1781 ; Cline was appointed Lecturer on Anatomy and Surgery at the school of St. Thomas's Hospital in his place, and, as was then the custom, bought his predecessor's museum and anatomical preparations of the executors. In December, 1784, Thos. Smith, the surgeon to whom he had been apprenticed, died, and Cline succeeded him. He was thus enabled to receive pupils, and amongst the first to be sent to him was Astley Paston Cooper, then a lively young scapegrace who soon strained the patience of his uncle, William Cooper, surgeon to Guy's Hospital, to whom he was first apprenticed. Cline exercised a control which was all for the good of Cooper, whom he soon converted into a hardworking anatomist, thus laying the foundation of his future greatness as a surgeon. Cline himself worked steadily at St. Thomas's Hospital as Lecturer on Anatomy and Surgery, gaining a reputation both as a good teacher and a successful operator. Practice, however, came slowly, and he did not consider himself firmly established until he had arrived at the age of forty-five. From this time onwards his income increased until, at the age of 60, Sir Astley Cooper estimated that he was making upwards of £10,000 a year, and adds that it might easily have been much more if he had been less fond of politics and farming. On



HENRY CLINE, SENR.

From a bust in the Great Hall of St. Thomas's Hospital.

November 11, 1793, he examined Edward Gibbon, the historian, and found that the swelling he had long considered a hernia was in reality a hydrocele. Cline tapped it, and drew off 160 ounces of fluid, and a fortnight later he tapped it a second time, drawing off 120 ounces.

In 1796 he moved to Lincoln's Inn Fields, then the fashionable neighbourhood for successful surgeons, and on July 7, 1796, he was elected a member of the Court of Assistants of the Surgeons' Company, in place of William Walker, who had died whilst one of the two wardens of the corporation. The election was a remarkable one, because the meeting of the court at which it was made put an end to the legal existence of the Corporation of Surgeons. This originated from the following circumstances : By the Act of Incorporation, 18 Geo. II, the Court of Assistants of the Company was to consist of a master or chief governor, and two governors or wardens, with other members, of whom it was enacted that the master and one warden, together with one or two ordinary members, should form a Court for the dispatch of business. On this occasion, William Walker, one of the governors, died in May, 1796; the other governor, John Wyatt, was lying blind and paralytic in Warwickshire, and was so ill that it was impossible to move him. When the Court met, therefore, the master—William Cooper—and some of the other assistants were present, but not *one* of the governors or wardens as ordained by the Act. The meeting was not a court legally, but those present proceeded with the business, and elected Cline into the Court. The legality of the action was disputed, counsel's opinion was taken, and it was found that the Corporation had been destroyed. A Bill was brought into Parliament to legalize the action of the Court, but was thrown out in Committee. It was then determined to apply for the establishment of a new body, and in 1800 a charter was granted by King George III to establish a College of Surgeons. The Surgeons' Hall in the Old Bailey was sold, and the new College was established on its present site in Lincoln's Inn Fields.

In 1808 Cline bought some land at Bound's Green, and becoming greatly interested in agriculture, lost much time and money in its pursuit. In politics Cline was a devoted adherent of Horne Tooke, whom he attended professionally when he was a prisoner in the Tower, and afterwards in his last illness. For many years he gave an anniversary dinner to Tooke's friends and supporters at his own house in commemoration of Tooke's acquittal. He was also a friend of John Thelwall—the political agitator—and showed him much kindness. He was greatly in favour of the French Revolution, and by his influence with leading men in Paris secured Astley Cooper's safety during a three months' residence there in 1792.

In 1811 Cline resigned his office of Surgeon to St. Thomas's Hospital, and was succeeded in it by his son Henry Cline, junior. In 1815 he became Master of the College of Surgeons, and in 1823 he was re-elected to the same position, which was now called by the more high-sounding name of President. He died on Jan. 2, 1827.

Cline's reputation has been somewhat overshadowed by the fame of his pupil and colleague, Sir Astley Cooper ; yet by his contemporaries he was held in very high esteem, both as a man and a surgeon. As an operator he was neat, cool, and determined. He seldom praised, and never censured ; the kindness of his disposition induced him to put the most favourable construction on the actions of others, and rendered his manners peculiarly mild and conciliating. He was never eccentric or sarcastic, and to him vanity, arrogance, or self-sufficiency were strangers. He was constitutionally reserved and solemn. Sir Astley Cooper says of him that he wanted industry and professional zeal, liking other things better than the study or practice of his profession. In politics, a democrat ; in religion, a deist. A good husband, son, and father. As a friend sincere ; as an enemy most inveterate. He was mild in his manners, gentle in his conduct, humane in his disposition, but, withal, brave as a lion. His temper was scarcely ever ruffled. He appears to have had but little literary aptitude, for the only publication bearing his name is a small quarto on the *Form of Animals*, issued in 1805, and reprinted in 1806 and 1809. It seems to be a matter of uncertainty whether ' Cline's splints ' for the treatment of fractures of the leg were employed by Henry Cline or by his son. Savigny's *Collection of Engravings representing the Most Modern and Approved Instruments used in the Practice of Surgery* was

issued in 1798. Plate IV, *Fig.* 3, shows "the cutting gorget of Mr. Cline, an instrument held in universal estimation." There is also a figure of a papier-mâché splint, which is attributed to Mr. Sharp. This splint is identical in shape with that which is known to us as 'Cline's,' even to the open angle at which the foot-piece is moulded. It is probable, therefore, that either Cline *père* or *fils* used this pattern of splint, made in wood instead of the more brittle papier-mâché, and that it thus obtained its name.

Of the younger Cline there is not much to record. He was born on Feb. 4, 1781, and was admitted to Mrchant Taylors' School at the end of 1791. In 1813 he was lecturing on anatomy at St. Thomas's Hospital jointly with (Sir) Astley Cooper, having succeeded his father as surgeon in 1812. Mr. South says of him, that he was "tall, sickly, and a very plain man, marked with smallpox, and very shy; but when he spoke his smile was most pleasing and agreeable; he wore powder, as was then the general custom; but his hair was most oddly dressed, a sort of *toupet*, with longish hair combed down straight and matted with pomatum and powder. An old friend of mine used to say he looked as if he had put his head in the dripping-pan on one side and the flour-tub on the other, but the simile would have been more correct had he said his hair had been well plastered down with butter and powder or with oxide of zinc ointment." He appeared at lecture in short knee-breeches, black stockings, and a brown coat. Cline's lectures began with the muscles of the head, starting with the occipito-frontalis and then going on to the face.

The contrast between the younger Cline and Astley Cooper was very great; the joyous manner of the latter had no correspondence in the former. He went on in a quiet monotonous tone and very slowly until the day's allotment was completed. But from his lectures no one got out under an hour and a half and sometimes even three-quarters. In the wards he was extremely kind to his patients. Both by example and authority he insisted on almost womanly tenderness in handling them, and carefully attended to little matters which added greatly to the patients' comforts, but by most others were regarded as too trivial to call for attention. He was a very good mechanic, but as an operator he was intolerably slow, for he thought that an operation ought to be done well, and did not much care how much time he spent in doing it. In private life Cline made himself beloved and respected by all who came into relation with him. He died of phthisis on May 27, 1820.

The bust by Chantry was presented to the elder Cline in 1811 by the subscription of his pupils. It was placed in the Museum of St. Thomas's Hospital, but now stands in the Central Hall of the present Hospital. There is a replica at the Royal College of Surgeons of England.

A CASE OF CONTUSION OF THE AXILLARY ARTERY.

By Lieutenant-Colonel J. F. DOBSON, R.A.M.C. (T.),
and Captain W. R. HIGGINS, R.A.M.C. (T.)

The case described below is an illustration of a type of arterial injury which is not often noted, but which is perhaps more common than is thought.

Pte. C. J. was wounded on Aug. 17, 1917, by a rifle bullet. He was admitted to a general hospital in France on Aug. 18, having received no active treatment.

The wound of entry was one inch below the middle of the left clavicle; the exit at the axillary border of the scapula, about the junction of the middle and lower third. Wrist-drop was present. The left radial pulse was smaller than the right. There was no swelling in the axilla; no bruit or thrill; no pulsation; no hæmorrhage. The entrance wound was clean, and the exit wound ragged. He bled freely when wounded, but did not faint. He noticed wrist-drop, and weakness and numbness of the hand immediately. Anæsthesia was incomplete in the ulnar and radial areas; the median was unaffected. Motor paralysis was present in the extensors of wrist and fingers; there was complete paralysis of the intrinsic muscles of the hand supplied by the ulnar, and weakness of those supplied by the median.

It was thought that the axillary artery had been damaged, if not severed, and that the inner and posterior cords of the brachial plexus had been lacerated.

Operation, Aug. 19.—The wounds of entrance and exit were excised. Some tearing of the scapular muscles was found. A curved incision (*Fig.* 1) was made from below the clavicle over the inner part of the pectoral muscles to the anterior fold of the axilla, thence passing outwards along the fold to the arm. A flap of skin was turned back. The pectoralis major muscle was divided close to its origin and turned outwards, exposing the pectoralis minor. This muscle was also divided close to the chest wall, and reflected. The axillary contents were now clearly exposed. Some extravasated blood was wiped away.

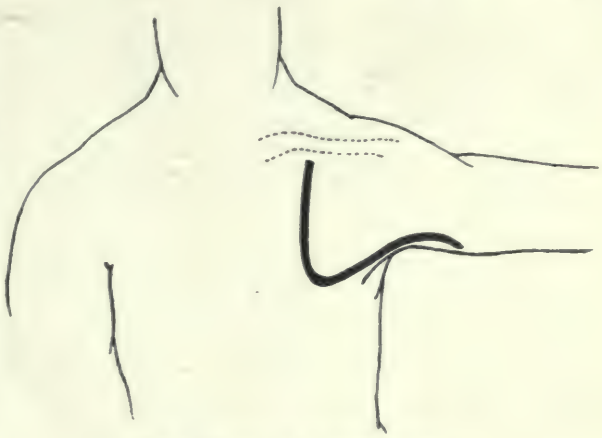


Fig. 1.—Diagram showing incision.

Axillary Artery.—At a point immediately above the crossing of the inner head of the median nerve, the artery presented a slight bulging, and appeared to be bruised. The artery was pulsating below this point, but on palpation of the damaged portion, the wall of the vessel felt thin, and after it had been handled a very slight weeping of blood occurred. The artery was ligatured above and below, and the damaged portion excised.

Brachial Plexus.—The inner cord, just above the point of division, had been partially divided by the missile. The posterior cord had been perforated by the missile, and was practically completely divided, the continuity of the nerve being maintained in part by the sheath. Both cords were repaired by suture of the sheath (00 catgut). The suture lines were covered with fatty fascial flaps taken from the lower part of the axilla.

The pectoral muscles were sutured, the axilla and exit wound were drained, and the entrance wound was left open. Both the wounds were swabbed with eusol, the axilla with saline.

Aug. 19.—Evening temperature 101°. Pulse felt at wrist.
Aug. 20.—Morning temperature 100°; evening temperature 101°. Pulse stronger.
Aug. 21.—Morning temperature 100°; evening temperature 100°.
Aug. 22.—Morning temperature 98·4°.



FIG. 2.—Open end of the resected portion of the artery, showing the laceration

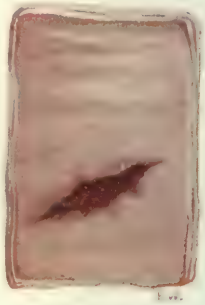
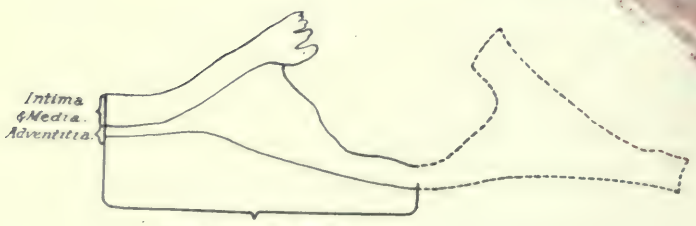


FIG. 3.—Appearance of the tear after slitting up the artery.



FIG. 4.—Microscopic section of edge of tear



Portion shown in Fig. 4.

FIG. 5.—Section taken transversely across the tear in the vessel wall.

The patient made an uninterrupted recovery, and was evacuated to England on Aug. 31. There was already some return of power in the extensors of the wrist. We have since heard that he is making good progress.

Specimen.—On examination, the specimen was seen to consist of three-quarters of an inch of the axillary artery, which was patent. On looking into the open end of the artery a tear of the inner coats could be seen, with the turned-up edges of the tear projecting into the lumen of the vessel and partially occluding it. After slitting up the vessel, the laceration was seen to involve about three-quarters of its inner circumference, and to extend through the inner and middle coats. The outer coat of the vessel was exposed in the floor of the laceration, covered with a thin layer of clot (*Figs.* 2, 3). *Figs.* 4 and 5 show a longitudinal section taken across the torn part of the vessel.

Captain M. J. Stewart made a section of the artery and gave the following histological report :—

> Microscopically, the tear is found to extend completely through the inner and middle coats of the vessel, the 'floor' being composed of the tunica adventitia, together with a certain amount of adherent thrombus. The torn edges of the tunica media and tunica intima project inwards into the lumen of the vessel, while the 'floor' of the tear bulges slightly outwards.
>
> There is a certain amount of separation of the media and adventitia at each side, and the angle thus formed is occupied by a mixture of recent blood-clot and fairly dense thrombus. The process is similar to that of a dissecting aneurysm in an early stage. The adventitial floor of the tear is much disorganized and infiltrated with blood, and altogether looks very insecure.

It is evident that the bullet had passed obliquely through the axilla, just damaging the inner cord of the brachial plexus, pushing the artery aside—the impact causing the fracture of the inner and middle coats—and then severing the posterior cord. Free bleeding occurred immediately after the injury, but it quickly ceased, and one cannot say with certainty whether it came from the main artery or from the damaged vessels of the scapular muscles.

Examples of partial laceration of the large vessels are not commonly seen. Delorme (quoted by Sencert[1]) described three degrees of contusions of arteries. In the first degree the inner coat only is damaged, and on opening the vessel fine linear scratches are seen such as might be produced by the point of a pin. In the second degree the inner and middle coats are torn, though the tear does not extend around the whole circumference of the vessel. In the third degree there is a circular tear through the inner and middle coats, with retraction of these layers. The specimen described above is an example of an injury of the second degree.

In considering whether the right procedure was followed in operating on this case so soon after the wound and on apparently somewhat insufficient grounds, one has to consider what would have happened to the damaged artery.

It is certain that some thrombosis would have taken place. This might have been partial, and it is conceivable that the tear would have healed without occluding the lumen of the artery, leaving a scar at the point of injury ; at some later date this might have occasioned the formation of an aneurysm. Fragments of the clot might have become detached and caused embolism in the vessels below. The artery might have been completely occluded with clot at the seat of injury ; in the absence of sepsis this would have organized and the vessel would have become obliterated ; one of us (J. F. D.) has met with an obliterated axillary artery twice during operations undertaken many months after the injury for lesions of the brachial plexus. It is possible that thrombosis might have spread upwards and downwards, obliterating the collateral channels, and giving rise to gangrene, as described by Sir George Makins.[2]

These do not seem, however, to be the most likely occurrences. Secondary hæmorrhage, or the formation of an arterial hæmatoma, is more probable. In this case the wound of entry was clean, but the wound of exit was rather ragged and dirty, and there was some laceration of the scapular muscles. Some degree of sepsis was very likely to occur, and if this had spread to the neighbourhood of the damaged vessel it would eventually have given way. If hæmorrhage or a rapidly increasing hæmatoma had resulted, an urgent operation would have been required, and it is unlikely that the immediate repair of the divided nerves would have been possible, particularly if the patient had lost any quantity

of blood. Even in the absence of sepsis, any rise in blood-pressure might easily have determined a hæmorrhage. The gentlest manipulation of the exposed artery during the operation provoked a little weeping of blood.

It may be asked why the damaged artery was not repaired by suture. In the first place, it was thought that the vessel might be contused for some distance, and that it would therefore be unsuitable for suture; secondly, ligature and excision of the damaged portion of the artery gave easy access to the divided posterior cord. The need for suture of the axillary artery does not seem to be demonstrated in such a case as this. Gangrene is practically an unknown event after ligature, in the absence of serious infection or gross injury to the tissues of the limb.

If it is conceded that similar cases to this should be explored, on what grounds can the injury be diagnosed? It will be noted that the patient was said to have bled freely immediately he was wounded. It is difficult to know whether this arose from the axillary artery itself or from other vessels. It seems almost inconceivable that the artery could have bled very freely and still have presented the appearance it did when exposed. On the other hand, though there was little internal clot, there was some extra-arterial clot, and the pressure of this may have checked the hæmorrhage. The only other symptom of arterial injury was a slight but definite diminution in the pulse on the affected side.

The nerve injury in this case was an additional reason for interfering, though it is usually not wise to repair nerves until the original wounds are healed.

The incision used is one which gives admirable access to all the structures in the axilla, with a minimum of damage to the pectoral muscles and their nerve supply. It is most useful in cases of injury to the brachial plexus when an operation is undertaken some months after the wound.

We desire to express our thanks to Colonel T. Gowans for permission to publish the record, and to Colonel Sir Alexander McCormick, A.M.S., for his advice and for the interest which he took in the case; also to Captain M. J. Stewart for the microscopic specimens.

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[1] Sencert, *Les Blessures des Vaisseaux*, 121.
[2] Makins, *Brit. Jour. Surg.*, 1916, iii, No. 11, 353.

BONE GROWTH AND BONE REPAIR.*

By Professor ARTHUR KEITH, F.R.S.

LECTURE II.

RESEARCHES MADE BY SYME AND BY GOODSIR REGARDING THE GROWTH AND REPAIR OF BONES.

My last lecture closed with the death of Hunter in London in the autumn of 1793. We shall now proceed to Edinburgh, to see what two men who made Edinburgh famous in the middle decades of last century—Syme the surgeon and Goodsir the anatomist—can teach us regarding the manner in which bones grow and heal. It suits our purpose, however, before proceeding to Edinburgh, to discover how bone surgery stood in the North of England during Hunter's time.

No one who values a knowledge of the history of surgery and of learning in England can afford to be ignorant of Charles White of Manchester. He was born in the same year as Hunter, 1728; he was a class-fellow of his in the Covent Garden School; through his long life he never wavered in his loyalty to Hunter's splendid abilities. He was elected a Fellow of the Royal Society long before Hunter. Cullingworth has assigned to him a foremost place amongst British gynæcologists; Cunningham has given him equal rank amongst the pioneers of British anthropology. He took a leading part in founding the hospitals, colleges, and learned societies of his native city, Manchester.

We propose to make his acquaintance in April, 1768, when Edmond Pollet, a country lad of fourteen, presented himself at Manchester Infirmary with an abscess in the left shoulder, the disease having commenced suddenly a fortnight previously. Pus was issuing by several sinuses situated in the pectoral and deltoid regions. If Charles White, then in the prime of his professional career, had followed the standard treatment of the period, he would have amputated the arm; but he resolved to try and save the limb by adopting a novel and conservative method of treatment. Making a deep vertical incision along the deltoid region, he forced the upper end of the dead shaft of the humerus from the wound and cut it off. Later, a further piece of the shaft was removed—altogether four inches of it. The arm was placed in a sling, so that "the weight of the arm might counterbalance the contraction of the shoulder muscles." Movement was permitted, to secure a sufficient degree of mobility at the shoulder-joint. In four months, to Charles White's surprise, the upper end of the humerus had been reproduced; there was only one inch of shortening, and the arm could be freely used. In reporting this case to the Royal Society in 1769, White drew two conclusions: (1) That when a bone was removed, the arteries of the part had the power to renew it; (2) That the operation of resection had manifest advantages over amputation, and deserved serious consideration as an alternative measure.

Charles White's novel operation of 1768 merely involved the resection of dead bone. In 1783, Mr. Henry Park, surgeon to the Liverpool Infirmary, was in a position to announce a further stage in the progress of surgery—the possibility of excising diseased joints as an alternative to the amputation of limbs. We merely note here that each of these innovations in the treatment of diseased bones and joints demanded a more intimate and exact knowledge of the life and growth of bone.

* Three lectures of a course on "Anatomical and Physiological Principles underlying the Treatment of Injuries to Muscles, Joints, and Bones," delivered at the Royal College of Surgeons, England.

Having thus seen the rise of 'conservative surgery' in the North of England in the later half of the eighteenth century, we pass on to Edinburgh to watch the practice and principles of James Syme. In his day Syme held the centre of the surgical stage; but it is only the early part of his career which interests us now—the struggling decade between 1823 and 1833, from his twenty-fourth to thirty-fourth year, when he was forcing his way up the Edinburgh surgical ladder. In 1825 there was sent to him a woman, Christian Laing, age 38, who had suffered from caries (tuberculosis) of the shoulder-joint for six years. Syme was brought face to face with the same problem as had been presented to Charles White fifty-seven years before—should he amputate, or should he resect the joint and thus try to save the limb? He chose the latter, and the woman did well. Resection as a defined operation for the relief of a diseased joint, was, as we have seen, first formulated in 1783 by Henry Park, surgeon to the Liverpool Infirmary, in a letter to Percival Pott; but the suggestion which moved Syme to adopt the operation came from a French source. Almost at the same time as Park was elaborating and applying the operation of resection to joints in Liverpool, Moreau, a surgeon in the North-East of France, was adopting a similar method of treatment, though it was many years later (1816) before his French colleagues recognized the value of his work. The first effort of Syme's youthful career was to introduce this operation into Scotland. In 1831 he published a *Treatise on the Excision of Diseased Joints.* By that date he had done fourteen resections of the elbow-joint. The introduction of a new surgical method invariably makes new demands on our knowledge of anatomy and physiology. The adoption of resection of joints as a routine measure made an exact knowledge of bone reproduction more urgent than ever.

If we would use words in a strictly conventional sense, we must describe Syme as eminently a practical as well as a daring surgeon. To the onlooker he seemed to apply a remarkably sound, common-sense judgement to the various surgical problems which came before him. In reality he was, as all purely practical men must be, an experimental surgeon, trying to discover the best means of treatment by roughly balancing the results which attended one method against those which followed from another. But for one brief period in his life Syme became a rational surgeon. In 1835—two years after he succeeded to the chair of clinical surgery in Edinburgh University—he had to treat the case of a young girl who suffered from acute osteomyelitis of the tibia. He had to amputate. When he dissected the leg, he found the shaft of the bone dead, and enclosed by a new stratum of bone which was adherent to, and apparently formed by, the periosteum. To settle for all time that periosteum could and did reproduce bone, he carried out the following well-devised—and, I have no doubt, neatly executed—experiment on young dogs.

In his first experiment he removed 1¾ in. from the radius of both right and left legs; on the right he also removed the periosteum, whereas on the left this membrane was preserved in place. When the dog was killed at the end of six weeks, the missing part of the left radius was reproduced; whereas, on the right, where the periosteum had not been preserved, a gap still remained. He repeated the experiment on a second dog, and got the same result: when the periosteum was removed, a gap remained.

He changed the conditions of the experiment. Taking another dog, he raised the periosteum from a segment of the radial shaft, and separated the periosteum from the bone by introducing between them a ferrule of tin-foil. The periosteum formed a layer of bone on the tin-foil.

Finally, he cut away the periosteum from a segment of the radius, and wrapped the denuded surface with tin-foil. No layer of bone was deposited on the tin-foil, because there was no periosteum covering it.

We have here the Haller-Duhamel controversy again raised, and it is clear Syme became a convinced Duhamelite.

We are now to make the acquaintance of a man who in his intimate and deep grasp of the problems presented by living matter came nearer to Hunter than any other Briton of the nineteenth century. In physical appearance John Hunter and John Goodsir were as different as men can be. Hunter was from the West, of medium stature, alert and fiery; Goodsir was from the East—from Anstruther in the county of Fife—tall, gaunt,

serious, and Calvinistic, with a long, sombre countenance. But Hunter and Goodsir were alike in this: they had an insatiable capacity for work, and an almost 'uncanny' gift of rightly interpreting, from the slenderest of clues, the more secret workings of living matter.

Here, however, we have to do only with Goodsir's investigations concerning the growth and reproduction of bone. Goodsir knew well about Syme's researches into the reproduction of bone by periosteum; he had 'dressed' for Syme; he was a student in Edinburgh and apprenticed to Nasmyth the dentist when Syme was rising to the height of his fame. There was every inducement for him to support Syme's conclusions; but the result of his investigations convinced him that the periosteum had no power to form bone, and that there was only one element in the body which could form and reproduce bone—namely, the corpuscles, which he had discovered and studied with his microscope as normal constituents in every variety of ossification. Goodsir was a Hallerite of a new kind.

No one can serve so well as Goodsir to bring home to us the transformation which took place in our knowledge of living bone in the decade which followed 1838—when men first came to realize that living matter is made up of units or atoms to which we give the name of cells or corpuscles. We are pursuing a straight path when we lay bare the circumstances which made Goodsir one of the pioneers of the cell doctrine. There are, in the first place, the circumstances of his training. He came of a line of medical practitioners. At the age of sixteen—in 1830—he was apprenticed to Nasmyth the dentist. He had the most delicate control of his long fingers, and very soon began to apply his manipulative ability to the investigation of tooth formation—which entailed a collateral study of bone growth. In Knox's dissecting-room he was thrown amongst the men who were to be leaders in science and in medicine—Edward Forbes, Fergusson, John Reid, and Sharpey. He dressed for Syme and dissected for Alison. In 1835 he became a Licentiate of the College of Surgeons of Edinburgh, and returned to Anstruther to assist his father. In three years he was back in Edinburgh in search of a foothold on the ladder which led to the more eminent posts in medicine. He had to wait until 1841, when he was twenty-seven years of age, before one came—the curatorship of the Museum of the College of Surgeons, at a salary of £150 per annum, out of which he had to pay an assistant. He only held the office for three years; but never did man crowd years with discoveries as Goodsir did these three. They were discoveries, we shall see, that have a very direct bearing on the problems we are exploring.

Goodsir brought to his office not only rare powers of brain and hand, but two qualifications which are absolutely essential for the man who would open a new field of knowledge—a new instrument and a fresh inspiration. The new instrument was the compound achromatic microscope, which had then been perfected by Lord Lister's father, and was Goodsir's companion from his boyhood upwards. His inspiration he drew from years spent in the study of the marine forms of invertebrate life which he dredged from the waters of the Firth of Forth. Molluscs, echinoderms, and sponges presented him with the same problems of life as did the tissues of the human body, but in a simpler form. He had the means of spanning the gap which seems to separate the hydra from the human body with much greater accuracy than was possible in Hunter's time. When he came to unravel the obscure and complex process of bone-building in the human skeleton, he found the clue from his work on sponges; they also build skeletons.

Goodsir was a follower of Hunter. In his youth he accepted Hunter's teaching that bone was deposited by arteries and was absorbed and remodelled by lymphatics. His microscopical investigations of the growing epiphyseal lines of bones revealed cartilage cells grouping themselves into serried ranks; he saw, or thought that he saw, these cartilage cells settle in the meshes of the cartilaginous trabeculæ and become "bone-forming corpuscles"; he traced the transformation of the primary spaces in the cartilage from one stage to another until they became Haversian canals, still lined by the cells which he regarded as the descendants of the primitive cartilage corpuscles. He saw how the corpuscles of the Haversian canals became included within the bone to become its living denizens. He knew that similar cells built up the skeletons of invertebrate forms

of life, and had no doubt that the human skeleton was laid down, not by arteries, but by an element of which Hunter had no conception—separate self-acting units of living matter. That discovery—Goodsir made it for himself, others had done the same independently—marks a new chapter in our knowledge of bone. But the old or Hunterian chapter did not pass out of date; the new chapter merely gave a more precise interpretation of the facts contained in the old. Bone corpuscles were substituted for arteries.

There were in the Museum of the Edinburgh College, under Goodsir's care, certain famous specimens which had been made in William Hunter's school in London by Cruickshank. They were supposed to demonstrate that lacteals opened on the intestinal villi by open mouths. Goodsir applied his microscope to these specimens; he could see the injected lacteals in the villi, but nowhere could he find openings or mouths. He applied himself to the problem of absorption. He fed a dog, and when digestion was at its height, examined the villi. He found cells laden with the products of digestion, and concluded that the cells which line the bowel were the agents by which food was taken up and absorbed from the contents of the intestinal tract. His intimate knowledge of cellular processes in the lower forms of life led him further; he realized that every cell in the human body must have a power of absorption. Absorption was a natural function of every kind of cell—including those which are found in bone. Thus, he had to throw overboard Hunter's conception of lymphatic vessels playing the part of bone absorbers and bone modellers, and put in their place simple units of living matter—bone cells.

The microscope revolutionized, and at the same time simplified, our conception of the growth, maintenance, and reproduction of bone. In place of it being a living tissue manipulated by arteries and by lymphatics, it became an organization of living units—bone corpuscles—each of them endowed with the power to build up or take down that territory which lay directly under its control. Goodsir was the first to realize the new picture of bone. That discovery has not made Hunter's assumption of 'consciousness' in bone less tenable. How are such cells controlled? What are the circumstances which make them lay down bone on one day and carry it away on the next?

The investigations which Goodsir made on the nature of bone, during the three years of his curatorship, are recorded in four very brief papers which first appeared in his *Anatomical and Pathological Observations*, published in 1845.* One of these is entitled, "The Mode of Reproduction after Death of the Shaft of a Long Bone." It is an inquiry concerning the bone-forming power of periosteum—being an answer to Syme's investigations mentioned in an earlier part of this lecture. He concluded that periosteum has no bone-forming power—it is simply, as he terms it, a 'limiting membrane.' He did not deny that periosteum "participated in the office of regeneration—an important principle in surgery," but its power to form bone depended wholly on the proper substance of the shaft which had become adherent to it. By actual experiment he removed periosteum by scraping, and found particles of bone adhering to its deep surface. From such fragments, he concluded, new bone was reproduced. He examined the periosteal shells which form round necrosed shafts. He found that wherever there was a rough or ulcerated patch on the old shaft, there was also in the corresponding area of the periosteum a nucleus of bone growth; but where the areas of the old shaft were perfectly smooth—where there was no trace of exfoliation or ulceration—there was a gap or cloaca in the overlying periosteal shell. If the periosteum owed all its osteogenetic power to adherent morsels of bone, then these appearances were just as they should be. He conceived that the shaft of a bone might be killed so quickly by disease that there was no time for the separation of living fragments to act as bone grafts on the periosteum. In such a case there would be no reproduction of bone. If the greater part of a shaft did die, he observed that ossific centres shot out most vigorously from the terminal living parts. He had never seen an epiphysis take any part in the regeneration of a shaft; in a physiological sense an epiphysis should be regarded as a separate bone. Finally, as regards Syme's experiments,

* See *The Anatomical Memoirs of John Goodsir*, by William Turner, Vol. ii., 1868.

Goodsir held that they did not demonstrate an osteogenetic power in periosteum, but they did demonstrate that, as detached by the surgeon, it could and did carry with it bone grafts which could serve as centres of reproduction. For Goodsir, a bone was a hive of bone corpuscles wrapped within a nest of periosteum.

I have mentioned Hunter's graphic and accurate picture of what the unaided eye can see when a living bone casts off a dead piece. Goodsir's paper on "Absorption, Ulceration, and the Structures engaged in these Processes" adds a fitting pendant to Hunter's picture—a pendant painted through his microscope—the earliest picture of its kind. We have seen that Goodsir recognized the corpuscles which lined the walls of the Haversian canals as the oldest and most active of the cellular constituents of bone. He had observed them on the surface of the bone, under the periosteum. He knew well that these canalicular cells could be stimulated to activity by inflammation; in Hunter's phraseology, they were endowed with irritability. He saw, in an inflammatory area of bone, that these cells multiplied in the Haversian canals: the walls of the canal widened by the proliferation of tissue and the absorption of the wall until neighbouring Haversian systems almost met, or did fully meet. He saw no impossibility in the cells which laid down bone changing their mode of life and devoting themselves to clearing away their old handiwork. He conceived that the more active these bone-devouring cells were, the shorter would be the term of their lives, and the sooner would they melt and their remains pass into the general circulation. By the proliferation of the cells in the canalicular systems an area of dead bone was separated from the surrounding living bone. The microscope simplified the understanding of the effects of inflammation on bone: Goodsir was the first to realize that these changes were effected by living units or cells.

Goodsir's bone researches were all carried out in the three years of his curatorship. In 1846, at the age of thirty-two, he was elected to the chair of Anatomy in the University of Edinburgh in succession to the third Monro. Just before the onset of his long, disastrous, and drawn-out illness, some ten years later, he opened up a field of research which yet remains to be explored. It is one which is destined to throw a new light on the living qualities of bone corpuscles. In 1853 a pupil had sent him a new form of sponge dredged from the waters off Spitzbergen. While investigating its structure, he observed that the spicules—its skeleton—had many forms, but each was built and laid down so as to strengthen and keep open the water-canals on the entirety of which the lives of the sponge colonists depend. He looked for the builders and found them. No one had seen or studied them before. He formulated the following law: "A spiculum is formed by a series of sponge-particles (sponge cells), so arranged in a column or system as, by the silicification of more or less of their contiguous surfaces and substance, to form a continuous rod." In short, he saw groups of spicule-forming cells marshall themselves into a geometrical pattern and lay down supports of the exact form and in the exact position where such supports were needed. We shall see that bone corpuscles have also similar qualities.

During the last ten years, Professor Dendy,* of King's College, London, and his former pupil, Professor Woodland,† have carried out a series of researches which justifies one in regarding the scleroblasts which form the spicular skeletons of invertebrate forms of life as the exact counterparts of the osteoblasts of our own bodies. In the more primitive types a spicule is actually formed inside the cell—an intracellular secretion; all stages between the intracellular and extracellular mode of spicular formation can be demonstrated. The scleroblasts are special cells derived from the dermal layer. They do their work according to the needs of the animal frame of which they form part; they build their spicules so as to strengthen that side of a sponge which is exposed to the force of the waves, just as osteoblasts built to withstand the pressures applied to bone. The scleroblasts, Professor Dendy observed, are sensitive to vibrations.

* For Professor Dendy's latest paper, see *Proc. Roy. Soc.*, 1917, lxxxix, 573.

† *Quart. Jour. Microscop. Sci.*, 1905, xlix, 231; 1906, xlix, 533.

OBSERVATIONS ON BLADDER INJURY IN WARFARE.

A STUDY OF 53 CASES.

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The word 'injury' has been chosen in the title of this paper, to include several cases which would not come under the heading of 'gunshot wounds.' A case of rupture of the bladder due to the falling-in of a dug-out, and two cases of bayonet wound, are thus included. Wounds of the bladder are comparatively rare. The percentage to total wounds reaching the base is probably not more than 1 in 3000 or 4000. For this reason it has taken some time to collect sufficient material to warrant the publication of this article.

The present communication is based upon a study of 53 cases. A few of these were seen at clearing stations, but the remarks which follow deal with the subject from the point of view of a surgeon working at the base. The very severe injuries which die at the aid posts, at the field ambulance dressing stations, and at the clearing stations, are therefore excluded. The final results are, unfortunately, not known in a considerable proportion of the cases, but enough material has been obtained to bring out the main points in the recognition and management of these injuries at a stage anterior to their evacuation to England.

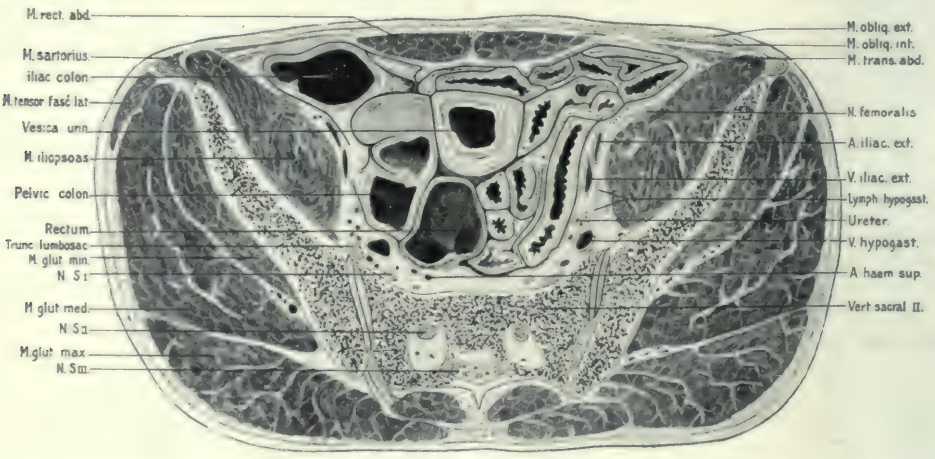


FIG. 6.—Upper surface of *Slab XIX* (Man 50). Note the small intestines lying anterior to the distended bladder. (×¼.) (*Crymble.*)

Anatomy.—It is unnecessary to describe the anatomy of the bladder in detail, but there are certain points which have an important bearing on the subject under discussion that may with advantage be brought to mind. In the collapsed state the bladder is a strictly pelvic organ, and occupies so little space that it forms a very small target for the missiles of war. When empty, it lies deeply in the pelvis, and, in a vertical antero-posterior section, is triangular in shape, being flattened above and below. When moderately distended, it still remains a pelvic organ. When fully distended, however, it becomes at its upper part an abdominal organ, and is likely to be injured by missiles entering above the

pubis. Occasionally coils of small intestine lie in front of the distended bladder, and may be injured by missiles entering the latter in this region (*Fig.* 6). It is reasonable to suppose that just before an attack the state of nervous tension practically always present will lead to an evacuation of the bladder contents; whereas, if the patient is caught unawares

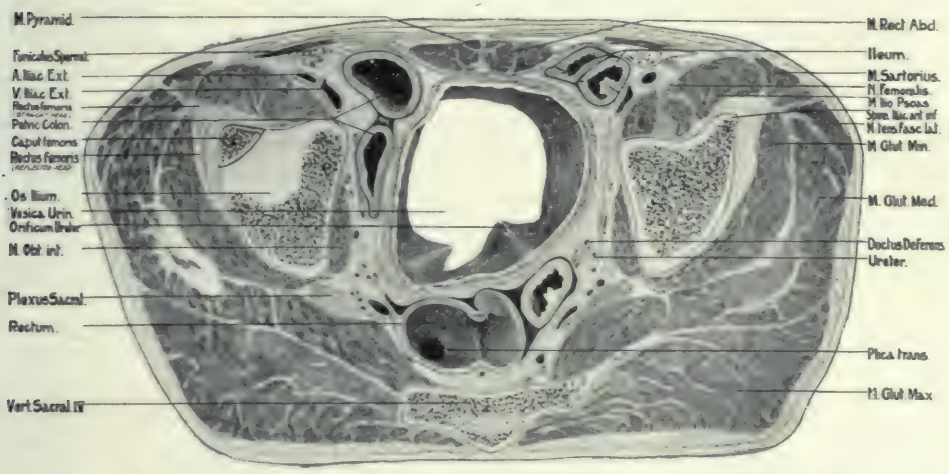


FIG. 7.—Upper surface of *Slab XX* (Man 50). Bladder distended. (×½) (*Crymble.*)

at other times, the organ may be in any state of distention. The *anterior* or *pubic surface* lies against the symphysis and body of the pubis and the deep layer of the triangular ligament. Only when the bladder is fully distended does this surface reach the lower part of the anterior abdominal wall. The space of Retzius lies anterior to the bladder, but

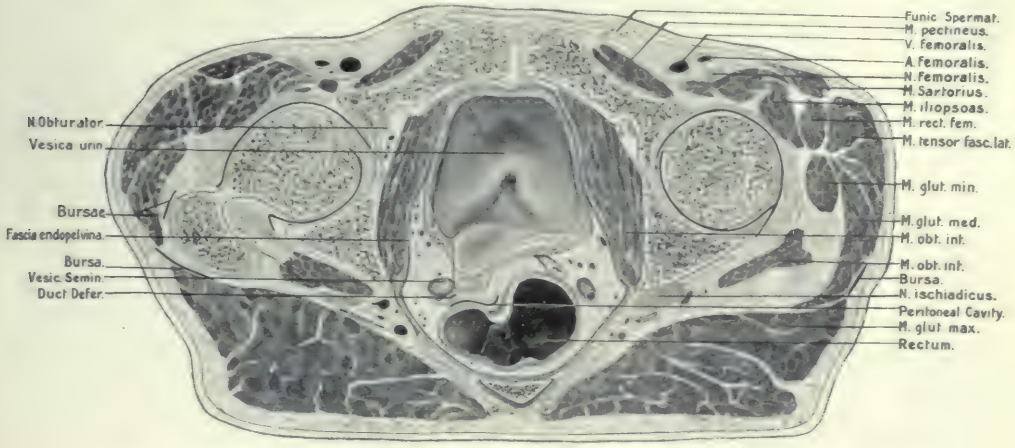


FIG. 8.—Upper surface of *Slab XXI* (Man 50). This section passed through the hip-joint, rectum, and base of the bladder. (×¼.) (*Crymble.*)

communicates freely with a similar space which extends laterally and backwards, internal to the levator ani muscle, to the posterior part of the rectum (*Fig.* 8). This fact has an important bearing on the question of extravasation of urine and the spread of pelvic cellulitis. The *base* of the bladder is its widest part. It lies against the rectum, and is

adherent to the bowel by dense areolar tissue, except for a short space above, where it is separated from this portion of the intestine by the reflection of the peritoneum at the lower part of the rectovesical pouch. This area of close apposition is bounded by the vesiculæ seminales and ejaculatory ducts of either side, which form a triangle with its apex at the prostate gland (*Fig.* 8). The sides of the bladder are crossed by the cord of the obliterated hypogastric artery, which marks the lower limit of the peritoneal reflection. All the area below this mark is extra-peritoneal (see *Fig.* 24). It is well to remember that the ureter and the vas deferens are in relation to the sides of the bladder, and the possibility of their injury in this situation must be borne in mind (*Fig.* 7). The *superior* or *abdominal* surface is free, and covered everywhere by peritoneum.

The prostate is so intimately connected with the neck of the bladder that it is frequently injured with it (*Fig.* 9). The gland rests posteriorly on the rectum at the point where it turns back to become the anal canal. Anteriorly it is half an inch or more from the pubic symphysis. The sides are embraced by the anterior fibres of the levatores ani. The apex rests on the upper surface of the triangular ligament.

The arrangement of the pelvic fascia is shown in the accompanying drawings.

The Missile.—In 1 case a missile (shell) was only indirectly responsible for an intraperitoneal rupture of the bladder ; the injury was caused by a fall of earth on the abdomen.

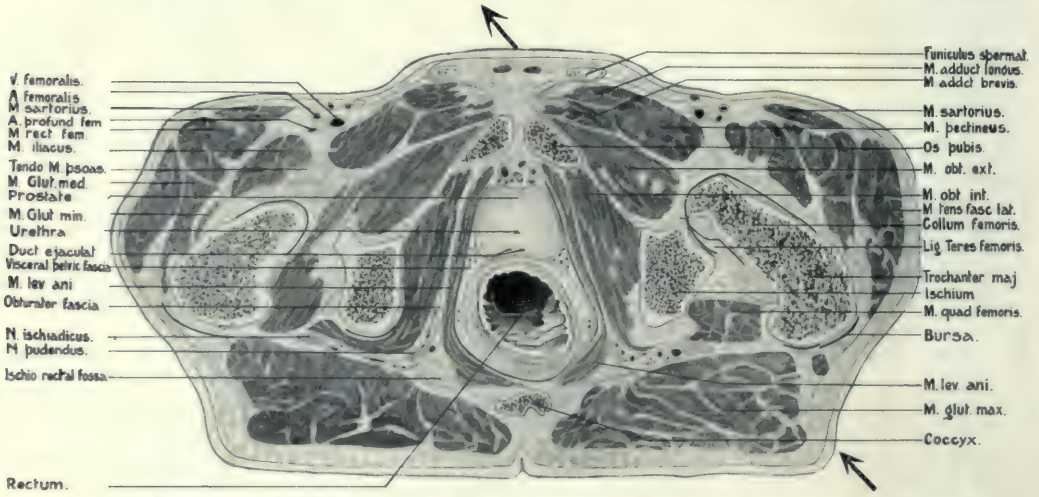


FIG. 9.—Upper surface of *Slab XXII* (Man 50). This section passed through the prostate and rectum. (×¼.) (*Crymble.*)

In 2 cases the injuries were caused by bayonet. In 24 cases the wound was caused by shell (including bomb, grenade, etc.) ; in 12 by bullet (rifle or machine-gun) ; in 7 by shrapnel ball. In 7 cases the nature of the missile was not stated.

Although wounds by shell are liable to be more serious, and to be attended with greater risk from sepsis, than those caused by bullet, the wounds by the latter were often very severe and septic. Of the fatal cases, 5 died of shell wounds, and 4 of bullet wounds, while death was due to a shrapnel-ball wound in 1 case ; in 2 fatal cases the nature of the missile was not known.

Track of the Missile.—In about two-thirds (34) of the cases the missile reached the bladder by way of the buttock. In 5 others there was an exit wound in the region of the buttock, communicating with the bladder. In nearly 75 per cent, therefore, there was a wound in the buttock region reaching as far as, or actually penetrating, the bladder (*Fig.* 10). The suprapubic route was comparatively rare. There were 4 cases with an entry wound in this situation, and 4 others in which the missile had either emerged by this route or had been retained in the suprapubic region. Wounds in the anterior abdominal wall, not suprapubic in position, rarely implicated the bladder. In 4 cases only did the missile

reach the bladder through the anterior abdominal wall, and there were no exits in this region. Wounds which shatter the symphysis pubis and lay open the bladder rarely reach a base hospital. Other routes were through the thigh, the groin, the iliac region, the loin, and the sacral or coccygeal region. In one case a bayonet wound reached the bladder through the perineum.

There were 13 through - and - through wounds recorded in the notes. The majority of these followed an oblique course; several passed from buttock to suprapubic region, or in the opposite direction; another route was from iliac region to perineum, another from groin to buttock, and another from thigh to sacral region. Antero-posterior wounds were somewhat rare; their course was from suprapubic to sacral or coccygeal region, or in the opposite direction.



FIG. 10.—Buttock wound through which the large fragment of shell shown in *Fig.* 23 entered. From *Case* 53 (22b).

Transverse wounds were seen occasionally; these passed from buttock to the opposite side across the neighbourhood of the hip-joint, or from buttock to the opposite groin. In 5 cases it was impossible to say whether there had been an exit wound, or whether the opening found had been due to an operation undertaken to remove a foreign body.



FIG. 11.—Exit wound produced by a bullet which struck bone and dropped back into the bladder. Note the surrounding ecchymosis. From a case more recent than the present series.

Reconstruction of the Track.—Entrance wounds in the buttocks, suprapubic, sacral, or coccygeal regions, or in the thigh or groin, ought to be carefully investigated. If a wound of exit is present, reconstruction of the track by sectional anatomy may indicate whether it is likely to have involved the bladder or not. If a foreign body is retained and it can be located accurately by radiography, the track may be reconstructed from the entrance wound to its ascertained position. In this way it will often be possible to determine with a fair degree of accuracy what structures have been involved in the passage of the projectile. The accompanying cross-sections (*Figs.* 6–9) are taken from a paper by Mr. P. T. Crymble,[1] and I am indebted to

him for his kind permission to reproduce them. A glance at these will show what structures are likely to be injured by wounds such as have just been described.

Fate of the Missile.—The foreign body was retained in 33 cases. In 10 of these it came to rest in the bladder. In most of the remaining cases it lodged in the pelvis or its walls, occasionally between the bladder and rectum. In one case the foreign body lodged just outside the bladder wall, while in another it was found later by cystoscopy to be embedded in the wall, in process of ulcerating its way through. A missile, therefore, may reach the bladder and contuse it, without doing further damage, as in *Case* 1 ; it may lodge in its wall, as in *Case* 53 (22b) ; it may enter its cavity and remain there, as in the 10 cases referred to ; or it may make a second opening in the bladder and emerge, to lodge in the

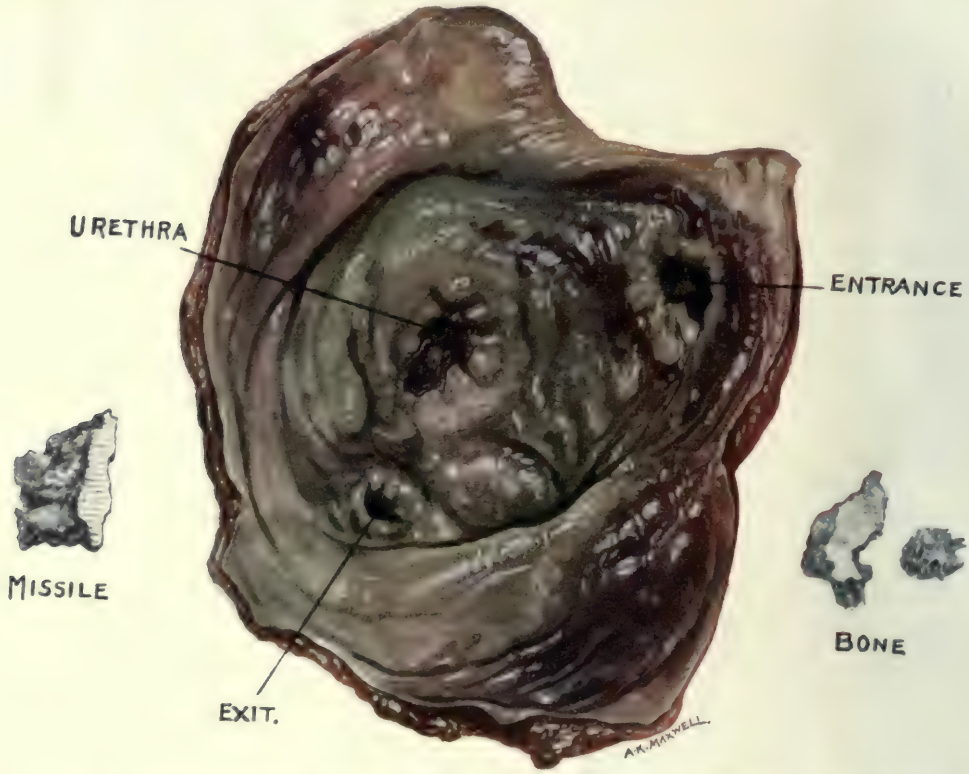


FIG. 12.—Through-and-through wound of bladder produced by shell fragment. The entrance wound is larger than the exit, probably on account of the in-driven bone being retained in the bladder. The exit wound involved the peritoneal cavity at the lower part of the rectovesical pouch, and communicated with the rectum. Note the ecchymosis of the bladder wall and the superficial necrosis of the mucous membrane. The missile had passed through the pubic bone, bladder, rectum, and sacrum, and lodged in the tissues behind. Death took place from gas infection in the track six days after injury. From a recent case.

pelvis or overlying soft parts, or to escape from the body altogether. In one case a bullet passed through the bladder but dropped back into it after striking bone—*Case* 13 (11a). In a few cases the wound was apparently tangential, the circumference of the bladder being injured at one spot only (see *Fig.* 15).

The Character of the Wounds.—The entrance wound, which, as has been stated, is often in the buttock, is frequently of small size and comparatively insignificant on superficial examination (*Fig.* 10). To reach the bladder a very considerable amount of tissue has to be traversed, and the length of the track may be six inches or more (*Figs.* 6–9). The more common large wounds of the buttock with which we are familiar frequently

stop short of the bladder. The bony girdle may arrest the missile before it reaches the depths of the pelvis, and the bladder may thus be spared. In the wounds under consideration, however, bone is often injured, and splinters may be driven into the bladder wall. The wound, therefore, is usually of the nature of a long fistula, the walls of which are often severely contused and liable to undergo a certain amount of necrosis. Along this track

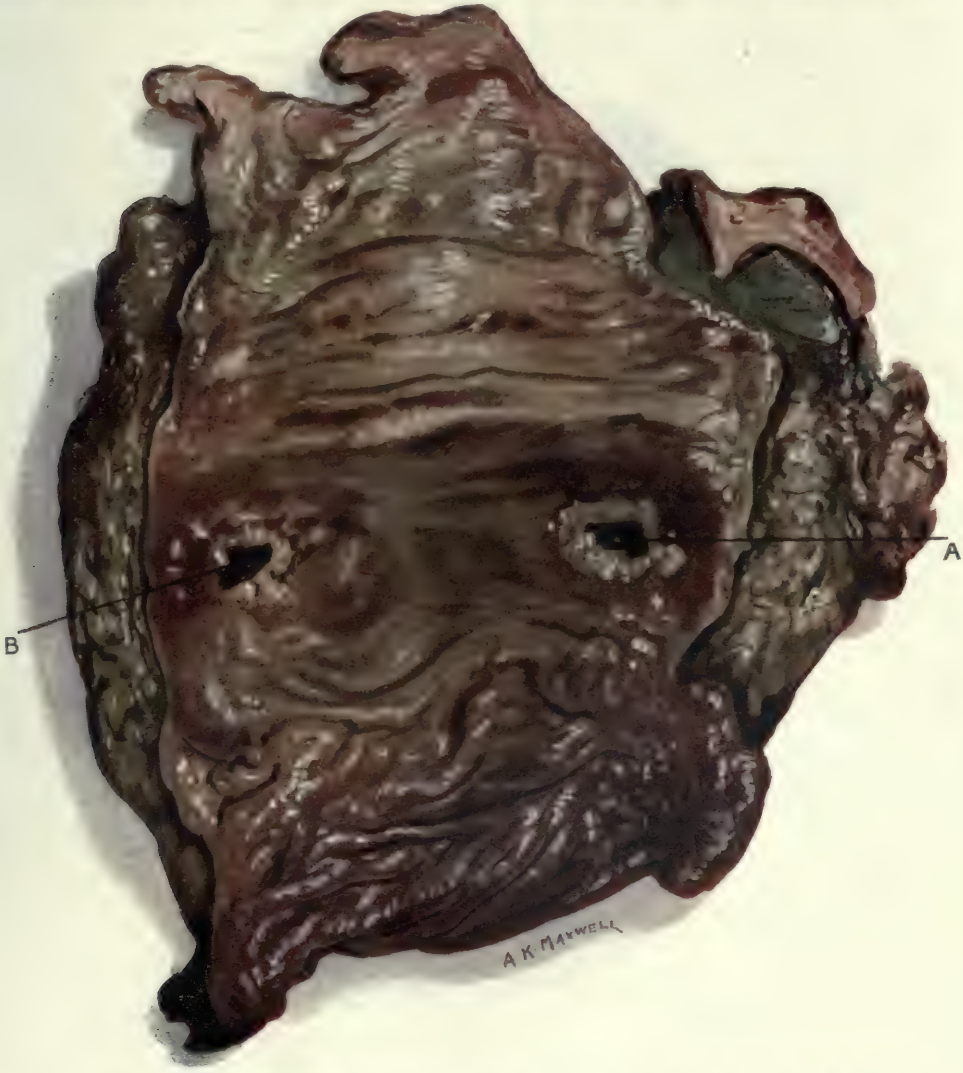


FIG. 13.—Rectum from same case as *Fig.* 12. Note the ecchymosis of the rectal walls, and the ring of necrosis surrounding the wounds of entrance and exit; also the gangrenous condition of the peri-rectal tissues.

urine and sometimes fæces may reach the surface. The frequency and importance of bone and bowel injury will be dealt with later.

The wound in the bladder itself was of the most varied nature. Sometimes it was a perforation, sometimes a tear or a slit, and in one case a considerable portion of the bladder wall had been shot away. In pubic wounds involving bone, the last condition is likely to be present—*Case* 41 (10b). When there is a peritoneal wound of exit, as in *Case*

27 (25a), the peritoneal coat may be split for a longer distance than the remaining coats of the bladder wall. There is likely to be a good deal of ecchymosis of the damaged walls in the vicinity of the wound (*Fig.* 11), and for some distance around, and this has in a few cases been demonstrated by cystoscopy (see *Fig.* 21). A wound of the bladder may be intraperitoneal only, as in *Cases* 7 (5a) and 45 (14b), or it may be partly intraperitoneal and partly extraperitoneal, as in *Case* 40 (9b). When entrance and exit wounds exist, there may be both an intraperitoneal and an extraperitoneal opening (*Fig.* 12), as in *Cases* 8 (6a) (?), 13 (11a), 21 (19a), 27 (25a), 31 (29a), 36 (5b), and 52 (21b), or both wounds may be entirely extraperitoneal, as in the remaining cases. (The case of intraperitoneal rupture and the case of contusion only are excluded.)

Associated Injuries.—The gravity of injuries to the bladder is greatly enhanced by associated damage to adjacent structures. In the present series 35, or nearly 70 per cent, were complicated by injury to intestine or bone, or both. In 26 cases (50 per cent) there was a wound of some part of the lower intestinal tract, and 13 of these were also complicated by osseous fracture. There were 19 cases of damage to the rectum (*Fig.* 13); in 3 of these there was an intraperitoneal wound; in the remainder the wounds were extraperitoneal. In 6 cases the small intestine was wounded, and in several of these the damage was such as to require resection of considerable lengths of gut. In 1 case there was a superficial wound of the peritoneal and muscular coats of the pelvic colon. In 22 cases (42 per cent) there was damage to the bones of the pelvic girdle. The pubic bone was fractured in 12 cases, once in association with the sacrum, once with the great trochanter, and once with the head of the femur, involving the hip-joint. In 1 case the notes state that the bones entering into the formation of the obturator foramen were damaged. The sacrum was fractured in 5 cases, once in association with the pubic bone. The iliac bone was fractured in 2 cases, once in association with the ischium. The ischium alone was fractured in 1 case. In 2 cases the coccyx was fractured. It is possible that bone injury may have been more frequent, and that cases of fracture may have escaped notice, when it was not practicable to have recourse to radiography. Legueu[2] found fractures in 25 of his 43 cases of bladder injury (over 58 per cent).

Wounds in the region of the neck of the bladder are liable to be accompanied by damage to the prostate, and the notes mention this complication as having been present in 7 cases. This estimate may be incorrect, as injuries in this region are difficult to locate with accuracy. I have thought it well to include these 7 cases as injuries to the bladder rather than the urethra, as it was difficult to ascertain the exact extent of the damage.

Other complicating injuries were present as follows. The anterior crural nerve was injured in 1 case, the sciatic nerve in 2 cases, the femoral vein in 1 case, and the spine (concussion) in 1 case; involvement of the spermatic cord, necessitating orchidectomy, was present in 2 cases. The position of the vesiculæ seminales and ejaculatory ducts renders them liable to injury when the bladder and rectum are simultaneously involved (*Fig.* 8); only in a few cases, however, was a diagnosis of injury to these structures made. Injuries in other regions of the body were occasionally present, and contributed to the gravity of the case.

The more important combinations of bowel, bone, and bladder injury met with may be summarized as follows:—

Structures Injured	Cases
Bladder, pelvic bone, and rectum	11
.. ,, ,, small intestine ..	2
Bladder and pelvic bone	9
,, ,, rectum	8
,, ,, small intestine	4
,, ,, pelvic colon	1

SIGNS AND SYMPTOMS.

No apology need be offered for dealing rather fully with the signs and symptoms that would lead one to suppose an injury had been done to the bladder. The remarks which follow will make it clear that these lesions may escape notice in the early stage when a comparatively simple operation may save life. Wounds in the buttock region especially must be regarded with the utmost suspicion until their direction and extent have been carefully studied. An intraperitoneal wound of the bladder or other pelvic viscus may be entirely overlooked, as in *Cases* 2, 20 (18a), 27 (25a), 31 (29a), and 47 (16b).

In *Case* 2 the patient gave a history of something falling across the abdomen when a shell struck his dug-out. There was a wound of the right leg and one of the scrotum. When admitted to a base hospital next day he had slight rigidity of the lower abdomen, did not complain of any pain, but was tender over the hypogastrium. A catheter drew off 30 ounces of urine, containing some albumin, a few pus cells, but no blood. Death took place four days after receipt of the wound. Post mortem, peritonitis was found, due to an intraperitoneal rupture of the bladder (*Fig.* 14). In this case the symptoms were very indefinite, and the recovery of 30 ounces of clear urine by catheter deceived the medical officer.

In *Case* 20 (18a) there was a wound in the left buttock. A catheter drew off 5 ounces of clear urine. The note from the clearing station stated that there was no vomiting, no true rigidity, and no dullness in the flanks. Death took place at a base hospital two days after injury. The post-mortem revealed four perforations in the small intestine, and a wound of the bladder communicating at the bottom of the pouch of Douglas with the peritoneal cavity; general peritonitis was present.

In *Case* 27 (25a) a piece of shell, entering by the right groin, had gone through the bladder and torn a hole in the rectum through its peritoneal surface. Laparotomy was performed at the base two days later, but the patient succumbed from peritonitis.

In *Case* 47 (16b) a shrapnel ball had entered by the right buttock and lodged in the bladder. The patient was evacuated to the base next day. On his arrival at hospital Colonel Elder diagnosed commencing peritonitis, and performed laparotomy. There was blood-stained, urinous-smelling fluid in the peritoneal cavity. The site of the leak was not clear, but peritonitis was already well established. The patient made a good recovery after removal of the fluid in the peritoneal cavity and suprapubic cystostomy.



FIG. 14.—Intraperitoneal rupture of bladder (*Case* 2). The peritoneal covering is split to a greater extent than the remaining coats of the bladder. Note the exudate due to peritonitis.

The fact that these cases escaped diagnosis in the early stages shows that symptoms of bladder involvement are by no means always definite and unequivocal.

Shock.—Shock is likely to be present when other severe injuries, such as extensive fractures of the pelvic bones or wounds of intestine, complicate the case. According to Wallace,[3] it is one of the chief causes of death at the clearing stations. It is important to remember, however, that shock may be almost entirely absent in certain wounds which prove later to have penetrated to the bladder or even to one of the other hollow viscera in the pelvic region.

Hæmorrhage.—Hæmorrhage, like shock, contributes largely to the high mortality of wounds of the bladder at the front. Cases with a history of severe hæmorrhage do not often reach the base. In the early stages severe bleeding may take place into the peritoneal cavity or from the external wound. Wallace[3] states that wounds of the pelvic veins are responsible for a great deal of the hæmorrhage. In addition to the bleeding which takes place externally and into the abdominal cavity, a considerable amount of blood is often found in the bladder. The urine voided or removed by catheter usually contains blood in greater or lesser quantity, but two of the cases just cited show that this important sign may be absent. In the cases arriving at the base the quantity varied from a slight colouring of the urine to large clots which distended the bladder. In some instances a considerable amount of ecchymosis in the skin and extravasation of blood in underlying tissues was present. This was apparent in several cases in the hypogastrium, the perineum, or the scrotum and penis.

Leakage of Urine.—Leakage of urine from the wound in the bladder is one of the most important accompaniments of injury to the organ. This may appear at the wound in the parietes, or be more or less concealed in the form of extravasation into cellular tissue or leakage into the peritoneal cavity. In cases reaching the base, a urinary fistula was most frequent in the region of the buttock. When the rectum was also injured, a rectovesical fistula usually resulted (*Fig.* 15), and urine either escaped into the bowel, or was discharged, often accompanied by fæces, from a wound in the parietes. The urine may escape from the entrance wound, from the exit wound when present, or from a wound made by the surgeon for drainage or the recovery of a foreign body. In some cases the appearance of the fistula may be delayed for a few days after the occurrence of the injury. In *Case* 36 (5b), for instance, urine did not make its appearance in the wound until three days had elapsed. This was, no doubt, due to the time taken for the disintegration and discharge of sloughs in the long fistulous track. Although it is quite common for urine to escape into the rectum, it has not been noticed in the cases under review that there has been much tendency for the fæces to be discharged into the bladder. The escape of gas by the urethra, however, has been noted, as in *Case* 32 (1b). The size of the communicating opening between the bladder and rectum will, of course, determine the occurrence of this disagreeable complication.



FIG. 15.—Sigmoidoscopic view, nine days after injury, of anterior wall of rectum, showing recto-vesical fistula, 2½ inches from anus, produced by a bullet which passed transversely between bladder and rectum. Note the central slough and the surrounding inflamed area. Recovery without operation.

In most of the cases of the present series there was a urinary fistula, and, as has been stated, the site was most frequently the buttock. Other situations were the suprapubic region, the ischiorectal fossa, the groin, and the thigh. In a few cases there was no fistula. In *Case* 25 (23a), for instance, though a foreign body $1 \times 1 \times \frac{1}{2}$ cm. in size was found in the bladder, no leakage took place through the parietes. In *Case* 28 (26a) (*Fig.* 21), where two minute foreign bodies were seen in the bladder, there was no leak at any time. In *Case* 15 (13a), it is perhaps doubtful if the missile had actually perforated the bladder; no leakage was observed.

Urine which has escaped from the bladder may fail to reach the surface and be extravasated into the perivesical tissue described in the paragraph on anatomy. Under these circumstances it may show itself as a diffuse swelling in the suprapubic region, or may be detected as a tumefaction in the pelvis by rectal examination.

Retention of Urine.—After an injury to the bladder it is quite common for the patient to be unable to micturate for two or three days. If the wound is small, distention of the bladder may occur and require the use of the catheter. This applies, of course, to those cases in which suprapubic cystostomy has not been performed.

Pain.—A sudden, sharp pain may occur when the bladder is struck. When the patient arrives at the base, however, pain referred to the bladder is not a constant feature. If a foreign body has been retained in the bladder, or if cystitis has supervened, the recognized symptoms of these conditions will be present.

Tenderness and Rigidity.—In a fair proportion of cases of bladder injury, even if entirely extraperitoneal, there is some tenderness and rigidity in the hypogastrium. The presence of these signs led to an incorrect diagnosis of intraperitoneal injury and to exploratory laparotomy in 5 cases. Nevertheless, with the cases previously mentioned in our mind, in which a timely laparotomy might have saved life, we are bound to admit that it is better to err on the safe side, lest an intraperitoneal perforation should escape attention.

Vomiting.—Vomiting is occasionally seen in cases of bladder injury in which the peritoneal coat is intact. On the other hand, it may be entirely absent in the first hours of an intraperitoneal lesion.

Fever.—As in most war wounds, fever is commonly present, and depends largely upon the amount of infection in the soft parts and bone. When it persists, pelvic cellulitis, abscess formation, osteomyelitis, or spread of infection to the kidney, should be suspected.

METHODS OF EXAMINATION.

In examining a case of suspected injury to the bladder, attention should be paid to the position and direction of the wounds, and to the accurate localization of foreign bodies, if present. Radiography will determine the presence or absence of bone lesions and the situation of retained projectiles; cystoscopy will discover a missile or bone fragment in the cavity of the bladder, or a lesion of its wall; and rectal examination will give valuable information as regards wounds of the lower bowel, fluid accumulations in the pelvic connective tissue, and palpable foreign bodies. Leakage of urine into the peritoneal cavity may fail to give rise at first to acute abdominal symptoms, so that a careful watch must be kept on all doubtful cases. Fluid issuing from a wound in the parietes may be diagnosed as urine by its smell, by chemical examination, or by its becoming rapidly coloured after subcutaneous or intramuscular injection of such substances as indigocarmine or methylene blue. The amount of urine escaping may be very small, most of the contents of the bladder being expelled by the natural passage, or the greater part of the urine may leak through the wound in the parietes. The quantity will vary with the size of the opening in the bladder, the length and calibre of the fistula, and the amount of swelling present in its walls. In a few cases of bladder injury leakage occurs only during efforts to micturate, or is increased thereby. As a rule, however, it is continuous and independent of micturition. In cases of injury to the urethra, on the contrary, leakage occurs only during micturition, unless the sphincteric apparatus of the bladder is also damaged. Fluid injected at the meatus readily escapes from the fistula, as a rule, in urethral injuries, whereas in bladder injuries this is not likely to take place until considerable pressure has been used and a larger amount of fluid has been injected. The distinction is of importance from the point of view of treatment. The integrity of the sphincter vesicæ is valuable in protecting the bladder from infection, especially if the urethral wound is made to communicate freely with the surface by an incision in the perineum. I have had the opportunity of examining several of these cases, and have found the bladder healthy, except when it has been infected by a catheter. Suprapubic cystostomy under these circumstances is unnecessary and harmful.

The position of the ureter as it skirts the pelvic wall should be kept in mind. A leak from the buttock may be due to an injury of this structure (*Fig.* 6). Cystoscopic examination with ureteral catheterization would prove invaluable in such a case.

Hæmaturia should raise strong suspicions of bladder injury, but it is necessary to emphasize the fact that cases of hæmorrhagic cystitis have been comparatively frequent during this war, and that this condition may be present in a wounded man apart from bladder injury. The following case illustrates difficulties that may be encountered. A man was struck with a large piece of shell in the loin at the level of the iliac crest. Forty-



FIG. 17.—Contusion of bladder wall produced by shrapnel ball. Ecchymosis, with large adherent clot. From *Case* 1, two days after injury.

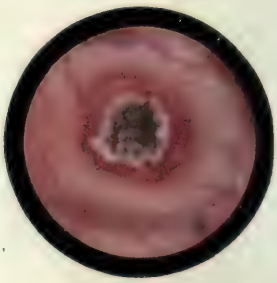


FIG. 18.—Wound of bladder wall behind trigone, produced by shell. Localized cystitis. From *Case* 6 (4a), six days after injury.

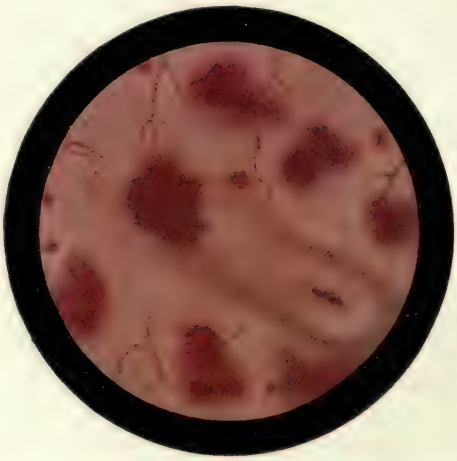


FIG. 16.—Hæmorrhagic cystitis following a wound in the lumbar region. No direct injury to kidney, ureter, or bladder.

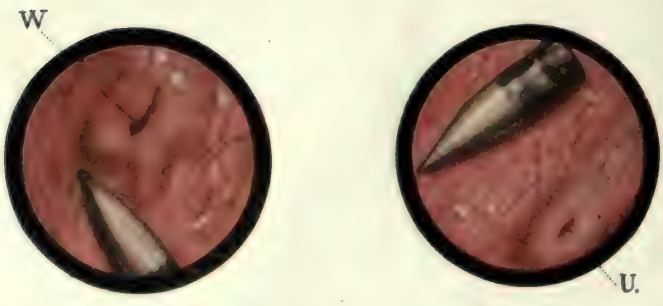


FIG. 19.—Wound of entrance and bullet in bladder. Moderate degree of cystitis W = Wound; U = Ureteric orifice. From *Case* 13 (11a), 13 days after injury.

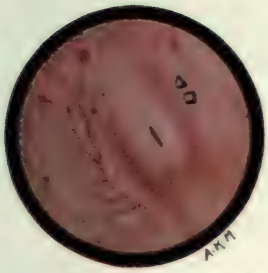


FIG. 21.—Two small fragments of shell in bladder. Patches of ecchymosis on mucous membrane. From *Case* 28 (26a), 3 weeks after injury.

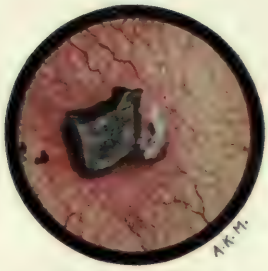




FIG. 20.—Shell fragment in bladder. Slight degree of cystitis. From *Case* 24 (22a), four days after injury.

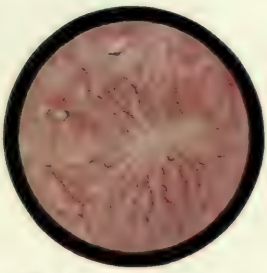
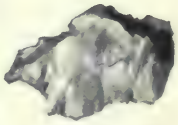


FIG. 22.—Scar on posterior wall of bladder after a wound by shrapnel ball. Mild degree of cystitis, and a few flecks of muco-pus. From *Case* 52 (21b), two months after injury.



CLOTH.





MISSILE.

FIG. 23.—Large piece of shell ulcerating through bladder wall. Note the adherent sloughs and the surrounding cystitis. From *Case* 53 (22b), thirteen days after injury.

eight hours later he had severe hæmaturia. On cystoscopic examination, we found intense congestion of the bladder wall, obliteration of the vessels, numerous patches of ecchymosis widely scattered, and films of muco-pus attached to the mucous membrane. Streptococci and staphylococci were found in the urine. When the cystitis had subsided, ureteral catheterization was carried out. The specimen from each ureter contained streptococci, albumin, some leucocytes, and a few red cells. Casts were also present. I was at first inclined to the view that we were dealing with a case of 'concussion' of the bladder from shell injury, but further experience would suggest that this was a case of hæmorrhagic cystitis, the infecting organism having probably gained entrance to the circulation by the wound. *Fig.* 16 represents the condition found when the cystitis had largely disappeared, leaving the patches of ecchymosis still unabsorbed. If there was any doubt in a similar case in future, the sigmoidoscope might be used to ascertain if any similar patches were present in the rectum. Patches in both bladder and rectum would favour the diagnosis of trauma.

Finally, if the surgeon is still in doubt, a measured quantity of bland fluid may be injected into the bladder, and the amount recovered ascertained. This is a clumsy method, and may fail to give the desired information. If a cystoscope is at hand, and the skill to use it available, a small aperture that might otherwise be missed may be discovered. As there is likely to be a good deal of ecchymosis in the neighbourhood of the wound, the surgeon may thus be guided to a perforation.

Cystoscopy.—Routine cystoscopic examination in bladder injury is not possible in war time. Nevertheless, I have been able to carry out this procedure in 11 cases, representing several types of injury. I have not had the opportunity of conducting examinations within the first few hours; the earliest period has been two days after injury. The following cases were investigated in this way:—

Case 1, in which a shrapnel ball had contused but not penetrated the bladder, was examined two days after injury. A hæmatoma of the bladder wall with an adherent clot was found. There was no cystitis (*Fig.* 17).

Case 3 (1a), in which a wound of the bladder, rectum, and sacrum had been produced by a bullet, was examined about a month after injury. A disappearing cystitis of moderate degree was found.

Case 6 (4a), in which a fragment of shell had produced a wound of the bladder, giving rise to leakage in the buttock, was examined six days after injury. Localized cystitis of moderate degree was found, and, behind the trigone, a circular aperture about a third of an inch in diameter and dark in colour. The last was probably an entrance wound, covered with sloughs, but it may have been commencing necrosis of the mucous membrane over the situation of a piece of metal known to be retained in the pelvis (*Fig.* 18). On the left lateral wall, a spot covered by a white membrane was seen. This was probably the site of an exit wound produced by a second piece of metal, also known to be retained further forward in the pelvis. An area of œdema and redness in the vicinity of the white membrane, and spots of ecchymosis posterior to the latter, were also seen. On the right side of the bladder, the vessels, though blurred, were visible. Flecks of muco-pus were seen scattered over the mucous membrane.

Case 9 (7a), in which a piece of shell had wounded the bladder and rectum and embedded itself in the sacrum, was examined eight days after injury. Cystitis was present, but no ecchymosis was seen. The aperture in the bladder could not be detected.

Case 13 (11a), in which a bullet had entered the bladder after producing six perforations in the small intestine, was examined thirteen days after injury. The bullet was seen lying free in the cavity (*Fig.* 19). There was a mild degree of cystitis, and some ecchymosis on the anterior wall, against which the bullet had impinged before falling back into the bladder. The wound of entry, previously dealt with by laparotomy, was represented by a slit in the mucous membrane of the posterior wall. Its slit-like appearance may have been due to the previous suture of the peritoneal surface by Captain Thomas at a clearing station. There was some redness and œdema around the wound. The lips of the slit were curled a little outwards.

Case 14 (12a), in which a shrapnel ball had wounded the bladder and led to leakage through the buttock, was examined ten days after injury. A small area, of deep-red velvety colour, with flecks of muco-pus on it, was found far back on the posterior wall, a little to the right of the middle line, surrounded by healthy mucous membrane. There was a good deal of redness around the left ureteral orifice. The aperture in the bladder wall could not be identified.

Case 22 (20a), in which a bullet had traversed the neck of the bladder or the prostate, shattering the pubic bone, was examined six months after injury. There was a moderate degree of cystitis, most marked at the base, and phosphatic débris on the way to become a calculus. Specimens

were obtained from both ureters, and were found to be free from albumin, pus, and blood. The aperture, being so far forward, was invisible by the cystoscope.

Case 24 (22a), in which a piece of shell had entered the bladder after having lacerated the rectum and prostate, was examined four days after injury. There was a mild degree of cystitis, and the foreign body could be seen lying free, surrounded by blood-clot. After washing away the latter a coloured drawing was made (*Fig.* 20). The urethroscope was now used to ascertain the position of the opening, which was found in the prostatic urethra, partially hidden by greyish, cauliflower-shaped granulations.

Case 28 (26a), in which two minute fragments of shell had entered the bladder, was examined three weeks after injury. There was a mild degree of cystitis, the vessels being blurred, but still visible. Two minute angular particles were found free on the bladder wall. Several small points of ecchymosis were seen on the right side, one or two just outside and above the ureteral orifice, and three or four on the right lateral wall (*Fig.* 21).

Case 52 (21b), in which a shrapnel ball had injured the coccyx, the rectum, and the bladder, was examined two months after injury. There was a slight degree of cystitis, and a radiating scar was seen on the posterior wall, with a leash of vessels converging towards it. The appearance is well seen in *Fig.* 22. A raw surface marked the position of the suprapubic wound, not yet completely healed.

Case 53 (22b), in which a fragment of shell had lodged in or near the bladder wall, was examined thirteen days after injury. Well behind the interureteric bar, near the middle line, an aperture was seen about one-third of an inch or so in diameter, with white adherent sloughs. The edges of this opening were red and swollen and rather sharply cut. There was much œdema and cystitis around. At the base of the bladder the vessels were blurred but still visible. After clearing away some of the sloughs with a stiff ureteral catheter, the foreign body was disclosed lying in a cavity communicating with the interior of the bladder. The coloured drawing represents accurately the state of affairs found (*Fig.* 23).

It will be noticed that in some of these cases the aperture in the bladder was not discovered. This is particularly likely to occur when the opening is near the neck, an area almost impossible to examine with the ordinary cystoscope. In the other cases the aperture may have been hidden by hæmorrhage or inflammatory swelling.

The presence of patches of ecchymosis appears to be a common feature, and this is what one would expect.

The degree of cystitis was very much less than might have been anticipated, especially with shell wounds, in several of which portions of clothing were known to have been carried in. In some the cystitis was local in character, and in all it was of a moderate degree of severity. Attention will be drawn later to two cases, not cystoscoped, in which a more virulent cystitis was present, and in which necrosis of the mucous membrane resulted ; on the whole, however, the condition of the mucous membrane of the bladder was a secondary feature in the case. This comparative immunity may have been due to the careful irrigation carried out in most of the cases; but one is driven to the conclusion that the mucous membrane in a healthy young subject is resistant to infection.

It is impossible to state the characteristic appearances of an opening produced by a missile from the cystoscopic findings here recorded. Large tears and perforations preclude the possibility of cystoscopy, and these descriptions must be regarded as examples of certain types of injury only.

COMPLICATIONS.

Pelvic Cellulitis is the most important complication of wounds of the extraperitoneal area of the bladder. There were 5 cases in the present series in which it was the cause of, or greatly contributed to, the fatal issue. The anatomical conditions which favour its occurrence and the direction of its spread have been already described.

Peritonitis.—Peritonitis is likely to occur when there has been an intraperitoneal injury to the bladder alone or in association with one of the other pelvic viscera. In the 4 cases in which it occurred it was due to an unrecognized lesion of small intestine, rectum, or bladder, and death ensued in 3 of these. In the remaining case, early recognition, followed by operation, saved the patient.

Extravasation of Urine.—As has been incidentally mentioned, a certain amount of extravasation of urine is likely to take place in extraperitoneal wounds. The infiltration takes place in the perivesical and perirectal connective tissue, but is not common between

the bladder and rectum at the area where these structures are closely connected by firm fibrous adhesions. In several cases it was an important factor. It produced sloughing of the scrotum in *Case* 43 (12b); in *Case* 48 (17b) the bladder was found on operation to be floated up as on a water-bed on a collection of urine which had extravasated from a lesion of the anterior wall; in *Case* 51 (20b), in which the prostatic urethra was found completely severed from the bladder, a large space was found at the base of the latter, filled with old blood-clot, urine, and fæculent material.

Cystitis. — It is probable that in every case of penetration of the bladder a certain amount of cystitis, local or general, occurs. In the cases examined with the cystoscope, the degree of cystitis was comparatively slight and the symptoms mild. In the present series the patients treated otherwise than by suprapubic cystostomy did not suffer from the scalding, tenesmus, frequency of micturition, and penile pain so common in severe cystitis in civil practice. The cystoscopic appearances in the few cases examined have already been described. In the following two cases the condition was sufficiently severe to cause necrosis of a considerable area of the mucous membrane. In *Case* 12b (43), treated by suprapubic cystostomy for a bullet wound of the lateral wall, a cast of the bladder came away later, on washing through the suprapubic wound. In *Case* 28a (30), already referred to, the patient died from pelvic cellulitis and gas gangrene of the ilio-psoas and muscles of the adductor region, following a bullet wound which traversed bone, rectum, and bladder. On post-mortem examination the mucous membrane over the greater part of the bladder was found grey and necrotic (see *Fig.* 12). Microscopical examination confirmed the diagnosis. The micro-organisms found in the urine, in the cases bacteriologically examined, included streptococci, staphylococci, and coliform bacilli.

Epididymitis.—This is liable to occur, first, when the prostatic urethra is involved, as in *Case* 11 (9a), and secondly, when the vesiculæ seminales or ejaculatory ducts have shared in the injury. In *Case* 17 (15a), in which the rectum was also involved, it is quite likely that the epididymitis spread back from the vesicula or the ejaculatory duct of that side. In *Case* 28 (26a) also it was thought that this was the cause of a severe epididymitis. There were, in all, 3 cases with this complication while the patients were in France.

Spread of Infection to the Kidneys.—As a rule the cases in the present series were not kept sufficiently long in France to allow time for the development of this complication. Whether it is a common occurrence or not will be shown by the future history of the cases, when that is available. *Case* 22 (20*a*) was examined from this point of view six months after an injury to the neck of the bladder. The sinuses in the buttock and thigh had not entirely closed at this date, as a large amount of bone had had to be removed for necrosis. The kidneys were quite free from disease, though cystitis had been present, probably for a considerable time. In *Case* 34 (3b) the post-mortem report states that there was some passive congestion of the kidneys and some pus in the pelves. In *Case* 35 (4b) suppression of urine occurred before death, but the post-mortem report states that there was no apparent kidney trouble. In several other post-mortem reports it is stated that the kidneys were healthy.

Osteomyelitis and Necrosis.—Cases with osseous fracture are frequently complicated by osteomyelitis and necrosis. In *Case* 22 (20a), for instance, a large portion of the right side of the pubic bone necrosed and was removed. Necrosed fragments were also removed in *Case* 11 (9a). Doubtless a number of the cases evacuated to England will require sequestrotomy.

Involvement of the Hip-joint.—This occurred in *Case* 22 (20a), and was due to the extension of a rarefying osteitis from the seat of fracture to the acetabulum. No suppuration took place in the joint, and the latter finally settled down with some restriction of movement. In *Case* 30 (28a) the hip-joint was involved, but the patient died before any symptoms referable to it became manifest.

Gas Infection.—There were 4 cases of severe gas infection, involving the abdominal wall in *Case* 8 (6a), the groin in *Case* 10 (8a), the adductor region in *Case* 30 (28a), and the glutei and psoas muscles in *Case* 44 (13b). In the last two cases it was a contributory

cause of death. In one of the fatal cases, 30 (28a), the mucous membrane of the bladder was necrotic, but it is difficult to say whether this was due to anaerobic infection or not.

Secondary Hæmorrhage.—In *Case* 9 (7a) very severe hæmorrhage took place on the twelfth day, shortly after an attempt to remove a foreign body embedded in the sacrum. In the other cases no hæmorrhage sufficient to call for special treatment occurred while the patients were in France.

Fæcal Fistula.—Fæcal fistula was present in 15 cases. In 14 of these it communicated with the rectum. In the remaining case, 8 (6a), the fæces appeared to come from the small intestine, twenty inches of which had been removed by a previous laparotomy. In this case fæces appeared in the abdominal wound on the ninth day after operation, accompanied by a discharge of urine. In many of the above cases the wound in the parietes discharged both urine and fæces. The position of the rectal wound or wounds can in some cases be found by digital examination, or, if this fails, by the sigmoidoscope.

Rectovesical Fistula.—Among the 19 cases of injury to the rectum, a rectovesical fistula was present in 13.

Fæcal Extravasation.—A small amount of pent-up fæcal extravasation in the perivesical space was found in *Case* 51 (20b).

Lung Complications.—Bronchitis of a severe type was present in *Case* 22 (20a), and pneumonia, probably septic, in *Cases* 34 (3b), 41 (10b), and 51 (20b). The latter was a very serious complication, and all three cases died.

Intestinal Obstruction.—In *Case* 45 (14b) adhesions took place between the small intestine and the spot at which an intraperitoneal injury to the rectum had been sutured. The patient died.

MORTALITY AND CAUSES OF DEATH.*

Wallace[3] gives the mortality of *uncomplicated* bladder wounds as 56 per cent, 14 deaths in 25 cases; he says, "in the cases of complicated wounds, the picture is dismal in the extreme." In the present series the mortality was over 24 per cent, 13 deaths in 53 cases reaching the base. The cause of death in these cases was as follows:—

Case 2.—Died from peritonitis due to an intraperitoneal rupture of the bladder caused by a fall of earth on the abdomen. Laparotomy was not performed. (See *Fig.* 14.)

Case 20 (18a).—Shell wound. Died from peritonitis following four perforations in the small intestine. There was, in addition, an extraperitoneal wound of the bladder and a fracture of the ischium. Laparotomy was not performed.

Case 27 (25a).—Shell wound. Died from peritonitis following an intraperitoneal injury to bladder and rectum. There was also a fracture of the pubic bone. A late laparotomy was performed at the base.

Case 30 (28a).—Bullet wound. Died of pelvic cellulitis and gas gangrene of the ilio-psoas, pectineus, sartorius, gracilis, and adductors, following an extraperitoneal wound of the bladder complicated by fracture of the pubic bone and head of femur and a wound of the rectum.

Case 32 (1b).—Shrapnel-ball wound. Died from pelvic cellulitis following an extraperitoneal wound of the bladder complicated by fracture of the symphysis and a wound of the rectum.

Case 34 (3b).—Shell wound. Died from pelvic cellulitis and septic pneumonia following an extraperitoneal wound of the bladder complicated by fracture of the iliac bone and the ischium. There was, in addition, a compound fracture of the bones of the right forearm and a wound of the left leg.

Case 35 (4b).—Bullet wound. Died of pelvic cellulitis extending downwards and backwards from the space of Retzius, following an extraperitoneal wound of the bladder complicated by a large rent in the rectum.

Case 37 (6b).—Nature of missile unknown. Died of pelvic cellulitis following an extraperitoneal wound of the bladder. There were no complicating injuries.

Case 9 (7a).—Shell wound. Died from hæmorrhage in the depths of the pelvis after an attempt to remove a foreign body. There was also an extraperitoneal wound of the outer coats of the rectum not involving the lumen.

* See corrections under 'Late Results,' p. 45.

Case 41 (10b).—Nature of missile unknown. Died of septic pneumonia following an extraperitoneal wound of the bladder complicated by an extensive fracture of the pubic bone. The anterior wall of the bladder had been torn away.

Case 51 (20b).—Bullet wound. Died of septic pneumonia following an extraperitoneal wound of the bladder complicated by injury to the prostate and rectum and fracture of the pubic bone and great trochanter of the femur.

Case 45 (14b).—Shell wound. Died of intestinal obstruction after suture of an intraperitoneal wound of the rectum.

Case 44 (13b).—Bullet wound. Died of gas gangrene of the glutei and psoas muscles with generalized anaerobic infection, following an extraperitoneal wound of the bladder complicated by fracture of the bones of the obturator foramen.

Of the gunshot wounds that proved fatal, 5 cases had, as complications, injury to the rectum and the bones of the pelvis, 3 had bone injury, 2 had injury to the rectum, 1 had injury to small intestine and bone, and 1 had no bone or bowel complication.

One of the most frequent causes of death was pelvic cellulitis. Of the 5 cases in which death was due to this cause, 4 were treated by early suprapubic cystostomy, and 1, *Case* 30 (28a), by drainage of the bladder through existing wounds.

TREATMENT.

In a previous communication,[4] I expressed views on the treatment of certain types of wounds of the bladder, which did not meet with universal acceptance. These views I still hold. In the present article the evidence upon which they are based will be given as fully as possible.

The indications for treatment in cases of injury of the bladder in warfare appear to me to be as follows :—

1. All foreign bodies, including missiles, fragments of bone, pieces of clothing, and blood-clot, should be removed from the bladder as soon as possible. This may be done by way of the original wound, by washing out through the urethra, or by cystotomy. If cystotomy is performed, the opening in the bladder may be closed by suture in suitable cases.
2. The wound in the bladder, if accessible, whether it be intraperitoneal or extraperitoneal, should be closed if possible.
3. After operation, care must be taken to keep the interior of the bladder clean by frequent and thorough irrigation until the urine is clear.
4. Careful attention should be paid to the perivesical and perirectal cellular tissue, to prevent, if possible, extravasation, accumulation, and the spread of pelvic cellulitis.
5. The wound in the parietes should be dealt with as thoroughly as the anatomical peculiarities of the affected region permit.

In the remarks which follow, it will be seen how far it has been possible to carry out treatment on these lines.

Intraperitoneal Wounds are usually treated by laparotomy at the clearing stations. A few which have not been operated on reach the base. The rent in the bladder should be treated by inversion of the edges and a continuous Lembert suture of catgut, reinforced, if necessary, by a second layer. The mucous membrane should be excluded, so as to avoid, if possible, the exposure of much suture material in the cavity of the bladder, where it may form a nucleus for the deposit of phosphatic concretions. In a few cases it has not been possible to get at the perforation so as to secure accurate apposition and a water-tight repair. In *Case* 40 (9b), for instance, Captain Hamilton Drummond found it impossible to deal with a perforation situated low down in the pouch of Douglas by the intra-abdominal route. He opened the bladder, therefore, and closed the perforation from within by a purse-string suture of catgut, reinforced by two additional sutures of the same material. A length of damaged small gut was resected at the same operation. The bladder was drained suprapubically. The case did well while in France.

In *Case* 52 (21b), again, in which there was an intraperitoneal perforation of both bladder

and rectum situated low down in the pelvis, Captain Sampson found it impossible to suture the apertures, and resorted to the expedient of shutting off the openings from the general peritoneal cavity by a line of sutures across the pelvic floor. A suprapubic cystostomy was performed, and an iliac colostomy. The patient was doing well when I saw him two months later.

In *Cases* 7 (5a) and 21 (19a), both of which were operated on by Captain D. C. Taylor at a clearing station, it was possible to close completely the intraperitoneal opening. In both cases there was also damage to small intestine, necessitating resection. Suprapubic cystostomy was not carried out, and a catheter was not tied in. Both made a satisfactory recovery, and were able almost immediately to pass urine in the natural way.

It would appear, therefore, that the ideal way to deal with these intraperitoneal injuries is to suture the perforation accurately, and refrain from suprapubic cystostomy and the tying-in of a catheter. If the union is not deemed to be watertight, as in the first two cases, suprapubic cystostomy, to prevent leakage into the peritoneal cavity, is the correct treatment. The management of cases with an extraperitoneal wound in addition is sufficiently indicated by what follows.

Extraperitoneal Wounds.—If there is a single extraperitoneal wound in an accessible position, and it is possible to suture the margins—after excision of the damaged edges, if necessary—it is good practice to do so. An exit should be provided in the parietes for escape of urine in the event of leakage taking place. This procedure is only possible in such situations as the suprapubic region, where the bladder approaches the surface of the body. If there are two extraperitoneal wounds, it is unlikely that both will be accessible. As a rule it is only the most dependent of these that leaks, and the surgeon will be guided by his experience and judgement, and by a consideration of some of the cases about to be cited, as to what course he is to pursue.

In *Case* 5 (3a) the entrance wound was close to the external abdominal ring. Captain H. F. Vellacott excised the edges of the rent in the bladder, and closed it with catgut sutures. Dirt and khaki were removed from the space of Retzius. The missile, a shrapnel ball, was retained between the bladder and rectum. Although leakage took place from the sutured bladder, the case did well.

In *Case* 12 (10a) a missile had passed from the buttock to the suprapubic region, fracturing the symphysis pubis. An extraperitoneal rent in the bladder, suprapubic in position, 1½ in. long, was sutured with fine catgut by Captain Shaw. Although blood and urine leaked from the wound in the buttock, the patient began to pass water twenty-four hours after operation, and was evacuated to England doing well.

In *Case* 16 (14a) an injury to the lateral wall of the bladder was sutured, and a small drain was placed in the neighbouring perivesical space. There was also a wound of the rectum, communicating with one in the buttock. A large drainage tube was passed through the buttock wound to the opening in the rectum. Lieutenant-Colonel Upjohn, who, later, had the patient under care at a base hospital, reports that the patient arrived in excellent condition. There was never any leakage of urine, and he was evacuated to England passing urine and fæces naturally. Extraperitoneal wounds situated in the neighbourhood of the base and sides of the bladder, and difficult of access, have given us a good deal of trouble and anxiety. These must be left, as a rule, to drain through the wounds in the parietes.

The two following cases illustrate a method of dealing with a cystotomy wound made to remove a foreign body in the bladder. In *Case* 13 (11a) Captain Thomas had closed an intraperitoneal wound in the bladder, and six perforations of the ileum. When the patient arrived at the base, a cystoscopic examination disclosed the presence of a bullet free in the bladder. The position of the bullet was located with the cystoscope, a pair of long dressing-forceps was pushed through the bladder wall by the suprapubic route, and the missile removed. The bladder was not further opened, and very little subsequent leakage took place (see *Fig.* 19). In *Case* 24 (22a) a piece of shell had entered the bladder by way of the buttock and rectum. Cystoscopic examination showed its presence and position in the bladder (see *Fig.* 20). Here, again, an incision in the suprapubic region was made down to the bladder wall, and a pair of forceps was pushed through to grasp and remove the missile.

The small opening in the bladder was sutured in this case, and no leakage took place at this spot, though urine still filtered to the surface through the rectal wound. The patient was sent home within a fortnight, and a letter was received from him a few days later to say that all his wounds were healed and that he was getting about.

In the subsequent management of cases such as those that have been described, one of the secrets of success is the attention given to the cleansing of the interior of the bladder. The method which has proved most satisfactory in my experience is the following : The bladder is thoroughly irrigated with plain boiled water until all shreds, mucus, and pus have been washed away. As soon as the water returns clear, a solution of nitrate of silver is used, beginning with 2 grains to the pint, and gradually increasing day by day to 8 or 10 grains. This procedure is repeated, at first daily, and then every two days, till the urine is clear. Under this treatment cystitis very rarely makes headway, and the patient is kept perfectly comfortable as regards his urinary organs. Some of the fluid escapes by the urinary fistula, if this is present, and washes it from within out.

The importance of the perivesical tissues can hardly be overestimated. In extraperitoneal wounds, if free exit is not provided, there is nothing to prevent the urine from extravasating round the base and sides of the bladder, to the posterior part of the rectum behind and the space of Retzius in front. The diagnosis of accumulation of urine and septic matter and of the onset of pelvic cellulitis will be made by pelvic examination and by attention to the pulse and temperature and the general condition of the patient. Treatment must be conducted on sound lines. Suprapubic cystostomy, even if performed early, does not seem sufficient. Of the 5 cases that died of pelvic cellulitis, 4 were treated by early suprapubic cystostomy. The following case, 51 (20b), will serve to illustrate the inadequacy of drainage through the bladder. A bullet had injured the prostate gland and neck of the bladder. Suprapubic cystostomy had been carried out at a clearing station. On arrival at the base the case was seen by Captain Bush, who recognized that the drainage was insufficient. Dissecting down on the bladder from the perineum, he struck a large space filled with old blood-clot, urine, and some fæcal matter.

Whenever it is desired to reach accumulations of fluid or collections of pus in the neighbourhood of the prostate and neck of the bladder, or to provide for drainage in this region, a transverse incision in the perineum between the anus and the bulb of the urethra, gradually and carefully deepened, gives the best access. The anal canal is drawn backwards and the bulb forward until the prostate is reached.*

Farther up, the rectum is so closely adherent to the bladder that collections are not likely to occur between them in this region, and it is not necessary to separate these structures. The part requiring drainage will be that lateral to the vesiculæ seminales, the side depending on the position of the wound in the bladder and the situation of accumulations if present. To reach this area, the following dissection may be done. Make an incision in the ischiorectal fossa parallel to and just medial to the ischiopubic ramus on the side affected. Pass the finger upwards medial to the obturator internus, and define the supero-medial boundary of the ischiorectal fossa—the levator ani muscle. The perivesical space can be entered by tearing through this muscle and its enclosing fascia. In making this dissection the surgeon will probably incise the base of the triangular ligament, but the artery to the bulb will be avoided by keeping posterior to a line drawn transversely from the bulb to the pubic ramus. In *Fig.* 24—a coronal section through the distended bladder and the prostate in a man age 40—the perivesical space is shown exaggerated in extent, and it will be seen how an incision through the levator ani will reach it at the point most suitable for dependent drainage. This section has been prepared for me by Mr. P. T. Crymble, and drawn by Miss Rea, to illustrate the perivesical space and the method of approach here recommended. In *Case* 11 (9a), I was able to deal somewhat in this fashion with an abscess cavity into which urine was being discharged from an injury near the neck of the bladder. Suprapubic cystostomy was

* To illustrate this method, a recent case of Captain D. C. Taylor's, not included in the present series, is briefly described at the end of ' Particulars of Cases ' (see p. 56).

not performed, as it was judged more satisfactory to deal with the case in the way indicated. The patient, who had necrosis of the pubic bone in addition, made a good recovery, and was evacuated to England with all wounds healed except a small fistula in the perineum. In *Case* 46 (15b) a somewhat similar procedure was carried out. The bladder was floated up by a collection of urine which had extravasated from wounds in the lower part of its anterior wall. A space surrounding the side of the bladder next the entrance wound in the buttock was thus easily reached and drained. The patient made a rapid and satisfactory recovery, and was evacuated to England, passing urine naturally and with all wounds healed, about three weeks after operation.

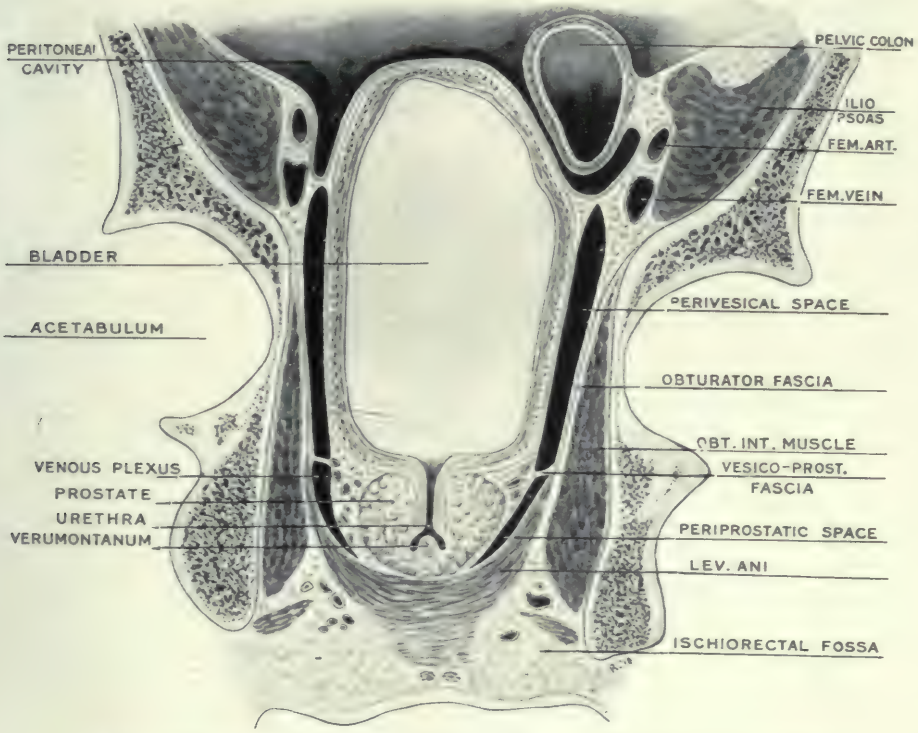


FIG. 24.—Coronal section through the distended bladder and the prostate of a man aged 40. The perivesical space is shown exaggerated in extent.

Treatment of the Wound in the Parietes.—As has been stated, the gravity of bladder injuries depends to a large extent upon the concomitant injury to the soft parts, the other pelvic viscera—particularly the rectum—and the bone. The wound is often so situated that excision of the track is impracticable for anatomical reasons. The best that can be done under these circumstances is to provide drainage, as free as possible, right down to the aperture in the bladder. Tubes, if used, should not enter the cavity of the latter. If the aperture is near the base, leakage, more or less, will probably occur whatever system of bladder drainage be employed. Free exit for urine must therefore be provided. If accumulation in the perivesical tissues and the depths of the wound can be prevented, the flow of healthy urine over the surfaces, even if bone or rectum be involved, will not be harmful. If, on the other hand, it is impossible by free drainage through the wound to prevent extravasation, a more suitable exit must be found by a dissection which leads directly to the injured area or the space in which the accumulation lies. I have indicated the lines upon

which such a dissection should proceed in the area most likely to be affected, viz., the base and lateral aspects of the bladder. Suprapubic cystostomy is insufficient to effect this drainage. If the bladder be not further mutilated by cystostomy, it will tend to contract upon its contents and drive them out through the wound, cleansing the latter in the process. The wound discharges are thus driven from within outwards by the force of the bladder contractions, and if the onset of cystitis can be prevented by careful lavage, the healthy aseptic urine will act as a continuous irrigator from the depths of the wound to the surface. If, on the other hand, the positive pressure in the bladder is removed by cystostomy, the organ collapses, and stagnation tends to occur in the tissues outside its walls. It is more likely that fluid accumulation will pass back into the bladder and infect it, if the *vis a tergo* which forces it to the surface has been lost, than under the reverse conditions. I am aware that these opinions run contrary to those of surgeons of great repute. Both Legueu[2] and Makins[5] mention cases of wounded bladder in which patients were not doing well, who improved after suprapubic cystostomy, but neither of these authorities mentions what attention was given to the bladder to prevent infection of that cavity. I can well understand that the urine from a badly-infected bladder would be injurious to a wound in the parietes, not to speak of the risk of upward spread to the kidneys; under these circumstances, cystostomy would be indicated. If, however, cystitis can be prevented, or efficiently controlled, I prefer, for the reasons stated, to avoid opening the bladder.

In the cases appended at the end of this paper, and those quoted in the text, I have marked all those treated without suprapubic cystostomy with the letter '*a*,' and those treated by suprapubic cystostomy with the letter '*b*.' There were, in all, 51 cases of perforation of the bladder (in one of these penetration was perhaps doubtful). Of these, 29 were treated without opening the bladder for drainage; 4 died, two of peritonitis from intraperitoneal lesions which had escaped notice at the clearing stations, one of hæmorrhage, and one of pelvic cellulitis and gas gangrene. The remaining 22 were treated by suprapubic cystostomy; 8 of these died, four of pelvic cellulitis (one of which had pneumonia in addition), two of pneumonia, probably septic in origin, one of intestinal obstruction, and one of gas gangrene. The two sets of cases were of the same degree of severity, and were almost identical as regards the percentage of associated injuries to bone, rectum, and small intestine. The late results are not known in all the cases, and it may be that cystostomy has been necessary later in the cases not so treated in France, for bladder or renal infection, for foreign bodies which have escaped notice, or for calculus formation. At the base, however, and I only speak of the cases that have come under my own notice, the best results have been obtained by the treatment I have outlined.

The Treatment of Associated Injury to Other Pelvic Organs.—Intraperitoneal injuries of the small intestine, rectum, or pelvic colon will be dealt with by laparotomy in the usual way. Extraperitoneal wounds of the rectum should be sutured, if possible; in most cases, however, this will be unsuccessful, and a fæcal fistula will follow. Many of these fistulæ do well without colostomy, but occasionally the wound in the parietes becomes so foul that an operation to divert the flow is necessary. This is specially indicated: (1) If there is a large communication between the bladder and rectum; (2) If an intraperitoneal wound of the rectum cannot be accurately sutured, as in *Case* 21b; (3) If fæces are discharged between the fragments of a compound fracture. If colostomy is necessary, the opening should always be made in the transverse colon, for reasons which I have mentioned in a previous paper,[4] viz.:

1. The stoma is far removed from the wounded area and from a cystostomy opening if present.
2. The opening is easily controlled.
3. Restoration of continuity is easily accomplished.
4. Should it become necessary later to remove part of a damaged rectum, the pelvic colon may be mobilized and brought down to supply the deficiency if it has not previously been interfered with by an iliac colostomy.

To these may be added :

5. The risk of a ventral hernia is less after a transverse colostomy than after one in the iliac region.

In the present series, colostomy was performed in 6 cases. In 3 the opening was made in the transverse colon, with 2 deaths ; and in 3 an iliac colostomy was performed, with 1 death. The result in the fatal cases was quite unconnected with the operation.

The treatment of rectovesical fistulæ which fail to close spontaneously is carried out at the home hospitals, and need not be described here.

LATE RESULTS.

The publication of this paper has been delayed in order to await replies to a number of inquiries made in England as to the after-histories of the cases upon which it is based These enquiries have been sent through the Medical Research Committee by Colonel T. R. Elliott, their representative in France, to whom I am much indebted for the trouble he has taken. The subsequent history of 21 cases has been ascertained, and I have thought it well to correct and complete as far as possible the account given in the preceding pages.

Additional Deaths.—Three additional deaths have to be recorded, bringing the mortality rate from 24 to 30 per cent. *Case* 8 (6a) died five weeks after injury, from what appears to have been intestinal obstruction. He had had about 20 inches of his small intestine resected in France. No post-mortem was made. *Case* 19 (17a) died in England eighteen days after receipt of his wound, but no further particulars are available. *Case* 22 (20a) died suddenly while straining to relieve his bowels, a little over six months after being wounded. His wounds were almost healed, and his urinary organs were functioning well at the time of his death. Post mortem, dilatation of the heart, with fatty degeneration of its walls, was found. The patient had passed through a long period of fever and suppuration during the early part of his illness, but had been apparently quite well for several weeks before his death.

Remaining in Hospital.—There were still 6 cases in hospital at periods varying from three to nine months after injury.

Unfit for Further Military Service.—There were 7 cases 'discharged unfit' at periods varying from five months to a year and five months after injury.

Back to Duty.—Only 4 cases are known to have returned to duty—*Case* 4 (2a) at the end of ten months, *Case* 23 (21a) at the end of five months, *Case* 39 (8b) at the end of nine months, and *Case* 47 (16b) at the end of four months after injury.

Complications and Sequelæ.—The following complications and sequelæ were noted in the replies received :—

Bone Injury.—In two cases bone injury was discovered in England which had been overlooked in France—in *Case* 19 (17a) fracture of the "pelvis," and in *Case* 29 (27a) fracture of the pubic bone. This raises the number of cases complicated by fracture from 42 to 45 per cent.

Vesical Calculi.—Vesical calculi were found in 4 cases. One of these, *Case* 18 (16a), had been treated in France without suprapubic cystostomy, and three, *Cases* 36 (5b), 38 (7b), and 46 (15b), had had suprapubic cystostomy performed at clearing stations. The calculi were discovered six months, ten months, and five months respectively after injury in *Cases* 16a, 5b, and 15b. In *Case* 7b the date is not mentioned.

Stricture.—In *Cases* 22 (20a) and 38 (7b), late reports state that dilators were required for commencing stricture. This sequela is likely to occur when the lesion is in the region of the prostate and neck of the bladder.

Secondary Hæmorrhage took place thirteen days after injury in *Case* 18 (16a). The patient recovered.

Sequestrotomy was necessary in *Case* 26 (24a) four months after injury.

Sciatic Pain on the same side as a buttock wound is recorded in the notes of *Case* 4 (2a).

Abscess in Testicle.—An abscess was found involving the testis and epididymis in

Case 36 (5b). Gonococci were obtained from the urethra, but there is no note of the organisms present in the abscess.

Epididymitis was recorded in the notes of *Case* 46 (15b). This probably spread from a cystitis which was present.

Cystitis and Pyuria.—Very few cases up to the time of writing were quite free from pus in the urine, and moderately severe cystitis was noted as being present in several. Some of these had been treated in France by cystostomy, and some without.

With these reports to hand the fate of nearly all the cases is known. Several were quite well on leaving France, and letters from a few others stated that they were convalescent. In *Cases* 17 and 50 a good deal of leakage of urine from the wounds was present on transference to England, and no reports have been received concerning their later progress.

Comment.—While these notes of after-results are very incomplete, they demonstrate certain facts of some importance.

1. Injuries of the bladder are of very severe import both as regards the life and the subsequent health of the patient.
2. The persistence of pyuria demonstrates the necessity for continuing bladder irrigation long after the wounds have been healed. When we have been able to keep the patients under observation and to carry out systematic irrigation, the results as regards cystitis and pyuria have been much better. Urinary antiseptics ought to be given in addition.
3. The development of calculi, as in *Case* 46 (15b), for instance, in which I cleared out all blood-clot and débris at the primary operation, is probably due to the subsequent separation of sloughs and the persistence of a certain amount of cystitis. Here, again, I feel sure that the continuance of frequent irrigation of the bladder would tend to minimize this risk.

Taken as a whole, the later results of injuries of the bladder are disappointing in the extreme, and suggest that constant, prolonged, and skilled after-treatment, in special hospitals if possible, is necessary if we are to look for any definite improvement.

CONCLUSIONS.

1. Injuries of the bladder form a very small proportion of the total wounds reaching the base hospitals.

2. Their importance from the point of view of prognosis and treatment depends to a large extent upon associated injuries.

3. The more usual associated injuries are those of the bones of the pelvic girdle and of other pelvic viscera. The most frequent viscus found injured in cases reaching the base is the rectum. Injuries of the pelvic colon and small intestine are comparatively rare in cases seen at the base.

4. The importance of the perivesical connective tissue cannot be overestimated. This forms a potential, continuous space extending from the cavum Retzii in front, round the sides of the bladder and rectum, to the posterior part of the latter behind. Pelvic cellulitis is a frequent complication.

5. The mortality of bladder injuries is very high. In cases reaching the base it may be estimated at 30 per cent. The chief causes of death have been pelvic cellulitis, peritonitis, and sepsis.

6. The chief sequelæ, judged from the reports reaching us from England up to the present, are necrosis of bone, persistence of cystitis, calculus, and stricture at the neck of the bladder. Sufficient data are not at present available to enable us to judge of the frequency of extension of infection to the kidney. J. Tanton[6] mentions that in a series of 137 cases of wounds of the bladder collected by him, 10 cases of pyelonephritis occurred, in 3 of which calculi formed requiring nephrolithotomy.

7. The treatment should be conducted on common-sense lines. Accumulations of infected fluid, blood-clot, and fæcal material in the pelvic connective tissue must if possible be prevented by attention to the original wounds. If this is unsuccessful, suitably

planned incisions should be made. The fact that urine flows over the surface of a wound is not necessarily in itself an indication for suprapubic cystostomy. If the bladder can be kept clean by irrigation, aseptic urine from the kidneys does not appear to have a deleterious effect on the wound.

8. Suprapubic cystostomy will drain an infected bladder, but will not prevent pelvic cellulitis and sepsis from occurring in the perivesical connective tissue and parietes respectively. The after-treatment of the bladder by frequent irrigation is necessary to get rid of cystitis and prevent calculus formation.

I desire to express my thanks to the officers who have assisted me with the notes of these cases; to the Medical Research Committee for the services of their artist, Sergeant A. K. Maxwell; to the latter for his keen interest and his careful delineation of the cystoscopic appearances; to Mr. P. T. Crymble, for permission to use *Figs* 6 to 9; and to Mr. P. T. Crymble and Miss Rea for *Fig.* 24.

PARTICULARS OF CASES.

In the descriptions of cases which are here appended it has been necessary to be as brief as possible. Only the main points in each case are mentioned, and the reports from England are abbreviated to give such information only as is likely to be of service to the medical officers who have had to do with the cases in France.

Case 1.—Capt. W., under care of Major Martin. Wounded by shrapnel ball Aug. 25, 1916. Entrance right gluteal fold. Fracture ascending ramus of pubis, right side. Admitted to base hospital, Aug. 27. Operation same day: cystoscopy showed hæmorrhage on bladder wall with attached floating clot (*Fig.* 17); foreign body together with some loose fragments of bone removed through suprapubic incision; shrapnel ball partially embedded in wall of bladder on right antero-lateral surface about 1½ ins. behind pubis. Urine leaked from suprapubic wound second day after operation; probably bladder was injured by bone fragments. Bladder irrigated with silver nitrate daily. Evacuated to England doing well, Sept. 9, 1916.

Case 2.—Pte. J. W., under care of Major McEwen. Wounded Aug. 12, 1917; penetrating wound of leg and laceration of scrotum. Gave a history of something falling across abdomen when shell struck dug-out. Admitted base hospital, Aug. 13. Bowels had not moved since accident, nor had patient passed urine. Catheter drew off 30 oz. of urine showing some albumin and a few pus cells, but no blood. General condition very poor; slight rigidity of lower abdomen. Bowels moved by enemata and pituitrin given every four hours. Aug. 14, began to vomit and hiccough: did not complain of pain; was tender over lower part of abdomen. Aug. 15, pulse weak and rapid, patient very listless; abdomen did not present any definite signs of peritonitis; slight dullness in flanks. Seen by consulting surgeon, who did not consider him fit for any operation. Death early next morning.

Post-mortem.—Intraperitoneal rupture of bladder (a longitudinal slit about 1¼ in. in length), and peritonitis (see *Fig.* 14).

Case 3 (1a).—Pte. A. F. S., under care of Captain Kelly. Bullet wound, Aug. 2, 1915. Entrance 1 in. above pubis and 1 in. to right of middle line; exit through third piece of sacrum to right of middle line. Bladder full at time of injury. Admitted base hospital, Aug. 8. A slight leakage from anterior wound; bulk of urine passing by large exit wound. Hæmorrhage. Rectum injured. Aug. 9, transverse colostomy. Irrigation of posterior wound with eusol. Wounds cleaned rapidly. Micturition normal early in September (about a month after injury). Cystoscopy showed cystitis of moderate degree. Discharged to England Sept. 21.

Report from England, March 2, 1916.—"Patient practically cured. Colostomy closed, and no discharge from remains of sinuses. About to leave for a convalescent home."

Case 4 (2a).—Sergt. A. L. Shell wound Oct. 3, 1915. Felt slight pain at time of injury. Later tried to pass water, and felt sharp, hot pain in region of wound; unable to pass water; no vomiting. Catheter drew off 8 oz. of blood-stained urine. Entrance wound in suprapubic region; exit left buttock. Catheter had been tied in at C.C.S. Cystoscoped Oct. 10: on anterior wall of bladder, aperture, plugged by muco-pus; orifice irregularly circular with œdematous edges; blood oozing from this orifice; patches of blood extravasation in neighbourhood extending as far as left lateral wall; cystitis; on left lateral wall an area indicating exit wound which is somewhat indistinct. (This cystoscopic examination was inadvertently omitted when describing cystoscopy in text.) Leakage same day from suprapubic entrance wound. Oct. 31, wounds dry.

Report from England states that three months after injury there were still traces of pus in the urine. Left sciatic pain was complained of. Wound of left buttock was healed on Jan. 2, 1916, and patient returned to duty Aug. 5.

Case 5 (3a).—Lieut. A., under care of Captain H. F. Vellacott. Wounded with shrapnel ball, about March 24, 1916. Entrance close to left external ring; no exit. Urine flowing from wound. Operation; laparotomy; peritoneum found to be only slightly wounded; reflected upwards; rent in bladder excised and stitched with catgut; dirt and khaki removed from cave of Retzius; drain to bladder stitches; laparotomy wound closed. Bladder wound began to leak, April 1; otherwise doing well. Stereoscopic radiography shows bullet near 3rd and 4th sacral vertebræ. Ball can be felt per rectum. Evacuated to England, doing well.

Case 6 (4a).—Rfm. H., under care of Major West. Shell wound, May 26, 1916. Entrance wound right buttock; no exit. No bone injury. No leakage of urine until May 30, when urine began to trickle through buttock wound independent of micturition. Temperature a little raised, 99°; general condition good. Radiography showed two pieces of shell in pelvis. Patient has urgency, but is unable to pass water. Urine foul-smelling and containing pus. June 1, cystoscopy: cystitis (appearances have been described in text). June 4, urine almost clear; bladder has been washed out with nitrate of silver solution. Track of missile: skin, gluteus maximus, great sacro-sciatic foramen, obturator internus and levator ani muscles, and vesiculæ seminales. June 13, evacuated to England, apparently quite well.

Report from England.—Wound healed July 1, about five weeks after injury. Feb. 2, 1917, discharged unfit for further service.

Case 7 (5a).—Pte. McK., under care of Captain D. C. Taylor, and subsequently of Major West. Shell wound, June 5, 1916. Entrance left side mid-axillary line, 1½ inches above iliac crest; no exit. At C.C.S., vomiting, pulse 140; blood in urine withdrawn by catheter. Scalp wound. Laparotomy by Captain Taylor; pelvis full of blood and urine; small intestine perforated in 11 places, with 2 tears in mesentery; four feet resected, end-to-end anastomosis; small hole in posterior wall of bladder just admitting finger; piece of shell in bladder removed and bladder sutured; abdomen closed, pelvic drain. Catheter passed every four hours. June 6, passing urine normally. June 14, wound in abdominal wall healed, except for track of drainage tube; patient quite well.

Case 8 (6a).—Pte. H. E., under care of Captain J. H. Thomas. Shell wound June 30, 1916. Entrance front of abdomen; considerable portion of abdominal wall blown away. Extensive gas infection. July 1, 20 inches of small intestine resected, end-to-end anastomosis; abdominal muscles partly pulled together with through-and-through sutures of silkworm gut; these cut out later, and the floor of the abdominal wound was formed by bowel. On ninth day, a fæcal fistula developed at upper end of wound. No hæmaturia, and he has passed perfectly clear urine without difficulty since his injury. Since operation, free escape of urine from depths of wound. Captain Thomas could see no perforation of bladder at time of operation; shell fragment had hit right side of symphysis and then passed into the thigh internal to vessels; fragment not removed. When seen at the base on July 18, huge wound in right iliac region, with urine flowing from lower part. All urine comes through wound; general condition good; some fæces coming through upper part of wound.

Report from England.—Aug. 1, bowels open, some urine leaking. Aug. 2, has been very ill, vomiting, no distention, pulse bad, wounds looking well, temperature 103°. Aug. 4, bowels will not act in spite of enemata, etc.; no marked distention, but incessant vomiting; died same day.

Case 9 (7a).—Pte. J. S., under care of Captain Bazett. Shell wound, July 2, 1916. Entrance right buttock; no exit. Said to have passed some blood per anum. Urine coming from two wounds in buttock. Large piece of shell in right side near sacro-iliac joint. July 10, cystoscopy; appearances have been described in text. Per rectum, some thinning of outer wall of bowel on right side and posteriorly along course of track. Urine contains much pus, coliform organisms, and staphylococci. July 13, small piece of shell removed from the smaller wound; larger piece embedded in sacrum; an attempt to remove this failed. Secondary hæmorrhage same day; direct transfusion of blood. Died July 17, from hæmorrhage.

Case 10 (8a).—Pte. J. F., under care of Captain Edye. Shell wound, July 9, 1916. Entrance wound right buttock near anus; passes into rectum and across latter to involve prostate. Shell fragment removed by Captain Edye, July 11, from left groin, where gas infection had developed. There were also two wounds in left buttock. Urine comes from rectum on micturition; none by the normal passage. There is a large hole in the prostate. Missile had gone through right side of rectum near anus, through anterior wall of rectum, and then out into left groin, where it was found just under skin; track lies internal to the femoral vessels. Radiography subsequently showed fragment of shell in the middle line behind pubis, and on a level with its upper border. Operation, July 12; fragment removed with a long pair of forceps through the wound in prostate and rectum. July 24, temperature normal; patient quite well; urine still coming per anum; passes some by normal passage. July 31, most of the urine coming per urethram.

Case 11 (9a).—Rfm. F. L., under care of Captain McDonnell. Shell wound, July 9, 1916. Entrance wound left buttock; missile tunnelled across rectum just inside anus, passing through

right side of rectum to the suprapubic region. Urine was coming from wound made at the C.C.S. in right groin, and from wound in buttock. July 14, radiography showed fracture of horizontal and descending rami of pubis at junction with body. July 27, condition good; wounds clean; urine from wound in buttock, fæces also through buttock; passed some urine per urethram. Aug. 25, temperature has been up for two days, 102° and 103°; urine coming from wound in right groin. Explored; necrosis of pubic bone; fragments removed; urethra found almost entirely divided at junction with bladder. Catheter comes out through wound in groin. Much pus. A small sinus in posterior wall of rectum leading to lumen just above external sphincter. Captain McDonnell reports pus in large quantities in urine; this evidently came from wound, and passed into urethra, as bladder when washed out was easily rendered clean. Aug. 26, operation; ischiorectal fossa explored; wound found to be in right side of prostate; large wound in groin, passing inside the pelvic wall to ischiorectal region; an incision which involved the right side of the triangular ligament at its base was made to counter-drain. Sept. 10, patient very well, passing water through perineal wound at will; wound in groin almost healed. Sept. 29, all wounds healed except that in perineum. Oct. 28, epididymo-orchitis on left side, settling down. Nov. 7, most of urine coming naturally.

Report from England.—March 16, 1917, discharged unfit for further service, about seven months after injury.

Case 12 (10a).—Lieut. M., under care of Captain Shaw. Wounded, Aug. 12, 1916. Entrance wound left buttock; large exit above symphysis, blood and urine flowing therefrom. Operation, Aug. 13; large extraperitoneal tear of bladder 1½ inches long; large fragments of symphysis detached, and others still adhering to periosteum; all pieces likely to cause damage removed; bladder stitched in two layers, catheter tied in, and suction drainage established for twenty-four hours; catheter then passed in the ordinary way every four hours for the next twenty-four hours. Blood soon disappeared from urine, and on following three days patient passed urine normally. Aug. 20, transferred to the base. Aug. 23, letter received from him stating he was doing well.

Case 13 (11a).—Pte. A. P., under care of Captain J. H. Thomas. Bullet wound, Sept. 1, 1916. Entrance wound right buttock; no exit. On admission to C.C.S., pulse 106; no vomiting; abdomen very rigid, no movement, no distention, painful and tender. Small amount of blood in catheter specimen. Laparotomy early next morning; large quantity of blood and clot in peritoneal cavity; no obvious urine; bullet had entered abdomen internal to right iliac vessels; laceration of mesentery of small intestine; 6 small perforations of ileum, all of them closed by suture; bullet had penetrated bladder at a point about half way up its superior surface; bullet could not be felt; perforation closed with a double row of catgut sutures; abdomen closed; prevesical space explored, and another small hole in anterior wall of bladder discovered; this was also closed with a double row of catgut sutures; it was thought that bullet had embedded itself in the symphysis; space of Retzius drained. Passed urine naturally without difficulty since operation; some hæmaturia for two days. Patient complained both before and after operation of the stream of urine being suddenly stopped, with a sharp spasmodic pain running down the penis. Radiography shows the bullet lying below the symphysis. Cystoscopic appearances have already been described in text; see also *Fig.* 19. Sept. 14, operation; bullet located by cystoscopy, and removed by forceps pushed through anterior wall of bladder. Very little leakage took place from this small wound. Evacuated to England, Sept. 16, doing well.

Case 14 (12a).—Pte. A. E., under care of Major West. Wounded by shrapnel ball, Sept. 15, 1916. Entrance wound right buttock. Bladder full at time of injury. Twenty-four hours later passed urine, and noticed blood in it, and that fluid came through the wound in the buttock at the same time. Missile retained. Urine only comes through buttock when he passes water. Pain in perineum just after micturition, lasting for fifteen minutes. Sept. 18, quantity of urine coming from buttock wound diminishing. Radiography shows shrapnel ball lying behind the ascending ramus of pubis at juncture with ischium. Urine contains much blood and pus. Sept. 21, no visible blood; temperature, which had been raised, is now normal. Cystoscopic appearances have already been described in text. Sept. 27, evacuated to England; normal temperature; normal micturition, and no evidence of cystitis.

Case 15 (13a).—Pte. T. F., under care of Captain Kelly. Shell wounds, Nov. 18, 1916. Many wounds of buttocks and thighs; peppered all over. Noticed blood in his urine a day or two later. Nov. 24, blood present in urine; no frequency of micturition; some suprapubic pain; burning pain on micturition. Radiography shows a piece of metal just in front of coccyx, to right of middle line, and another very small piece in the abdominal cavity to left of middle line, 3½ inches above level of symphysis pubis, about 1½ inches in front of second segment of sacrum; this has apparently gone through the bladder from below up; several pieces scattered about right hip-joint, and several present in buttock. Nov. 26, blood, albumin, and pus still present in urine. Dec. 3, running a temperature up to 103°. Dec. 11, evacuated to England, with blood still present in urine.

Report from England.—Aug. 17, 1917, discharged from hospital no longer fit for war service, nine months after injury.

Case 16 (14a).—Lieutenant-Colonel Upjohn's case. Wounded left buttock, nature of missile not stated. Injury to rectum and lateral extraperitoneal bladder wall. Laparotomy; bladder

sutured; small drain to perivesical wounded tissues. Never any escape of urine. Rectum drained by a large tube in buttock wound. Patient arrived at the base in excellent condition, passing urine and fæces naturally. Evacuated to England the following day. Nothing further is known of this case.

Case 17 (15a).—Sgt. F. C., under care of Captain Bush. Wounded, probably by a bullet, April 9, 1917. Two days after injury, explored through buttock wound, which was very foul, and communicated with rectum and bladder. Urine leaking through rectum and wound in buttock. Retained at base hospital for fourteen days. Left-sided epididymitis. Evacuated to England, not yet passing urine naturally.

Case 18 (16a).—Pte. R. W. W., under care of Lieutenant-Colonel Upjohn. Bullet wound, April 9, 1917. Entrance left buttock or thigh, to suprapubic region. Urine escaping freely from 2 slit-like groin wounds. Wound in buttock opened up; iliac bone found perforated; wound in right groin opened up. Eighteen days after operation, passing urine almost entirely per urethram.

Report from England.—April 22, secondary hæmorrhage from buttock. Oct. 13, calculi passed per urethram. Nov. 27, some small calculi have come away recently. Dec. 6, seen by Mr. Thomson Walker, who suggested constant irrigation of bladder. Dec. 11, condition greatly improved; taken off constant irrigation. Jan. 18, 1918, still in hospital, nine months after injury.

Case 19 (17a).—Pte. W. E. W., under care of Captain Reford. Wounded, April 9, 1917, nature of missile not stated. Entrance right buttock, traversed pelvis, and emerged in front of great trochanter of opposite side. No operation. Hæmaturia. April 14, urine emerging from exit wound, none from buttock or perineum.

Report from England.—Fractured pelvis. Ruptured bladder. Died, April 27, 1917. No further details available.

Case 20 (18a).—Pte. E., under care of Captain Hemmans. Shell wound, April 9, 1917. Field medical card lost, no notes from clearing station. Admitted base hospital April 11. Temperature 97·4°, pulse 132. Patient very ill; restless; abdomen tender in lower part, no true rigidity; no dullness in flanks. Catheter drew off 5 oz. clear, highly-coloured urine. Per rectum, nil. Wound of left buttock at level of great trochanter; finger in wound detected fracture of the ischium, and disclosed a cavity containing a large quantity of offensive, blood-stained fluid with urinous odour. Patient never rallied, died same day.

Post-mortem.—Diffuse peritonitis, especially in pelvis; four perforations in lower ileum; recent adhesions; large piece of shell about size of an almond lying within peritoneal cavity. Large hole in base of bladder. Compound comminuted fracture of spine of ischium. Wound in bladder was extraperitoneal. Missile had passed on, after wounding bladder, through rectovesical pouch to left side.

Case 21 (19a).—Rfm. O., under care of Captain D. C. Taylor, and subsequently of Major McEwen. Bullet wound, May 22, 1917. Entrance right iliac region; exit in perineum 1 in. in front of anus. At C.C.S., vomiting; hard, rigid abdomen. Laparotomy, six hours after injury, by Captain Taylor; free blood and urine in peritoneal cavity; small bowel cut across; another large tear sutured; 8 inches of ileum resected, and end-to-end anastomosis; a tear, 1½ inches, in right side of bladder sutured with double layer of sutures; abdomen closed without drainage. Patient has passed urine naturally since operation. May 29, has made good recovery; has no symptoms other than a little distention; not necessary to pass catheter; laparotomy wound healed by first intention. Seen at base, May 30, patient quite well; temperature and pulse normal; bowels acting well; passing urine normally. June 11, patient quite well.

Case 22 (20a).—Pte. W. L. H., under care of Captain Swan. Bullet wound, June 27, 1917. Entrance right buttock, outside and a little posterior to anus; exit same side, inner side of femoral vessels. June 28, escape of urine by buttock wound. Pubic rami shattered; prostate injured, Has passed some blood per urethram. Urine leaks during micturition. Blood, pus, coliform bacilli, and streptococci in urine. Had bronchitis and was very ill with high temperature for weeks. Large loss of bone. Bladder washed out daily. July 23, pieces of necrosed bone removed. Lotion injected per urethram comes out of wound. Aug. 4, pain and rigidity in hip of affected side. Aug. 20, passed some urine per urethram. Radiography shows rarefying osteitis of acetabulum and head of femur. Still running an evening temperature of 101° to 102°; it comes down for a few days and then goes up again. Hip fixed in splint. Sept. 24, passed about 20 oz. of urine naturally. Oct. 11, still some urine from wounds. Oct. 27, abscess in left groin, which had tracked from opposite side, opened. Nov. 8, temperature now settled; passing urine normally; no frequency; urine almost clear. Dec. 3, cystoscopy—appearances have already been described in text; some difficulty in introducing instrument owing to commencing stricture in prostatic urethra. Dec. 31, apparently no leak. Jan. 3, 1918, died suddenly from cardiac failure, a little more than six months after injury.

Post-Mortem.—Cardiac degeneration.

Case 23 (21a).—Dvr. W. W., under care of Captain Dawes. Shell wounds, July 2, 1917. Entrance left buttock, large wound. Foreign body removed. All urine by buttock wound. Other wounds on buttocks. July 8, fæcal-smelling discharge coming from buttock wound, probably due to a large slough, which was removed by Captain Dawes. Running a moderate temperature

up to 101° in the evenings. July 23, some urine per urethram. July 31, passed per wound large slough with very offensive smell, apparently from bladder. Aug. 6, most of urine per urethram. Aug. 22, wound dry. Sept. 16, urine clear; pain in the area of distribution of external popliteal nerve. Wound quite healed; marked for evacuation.

Report from England.—Oct. 31, radiography shows no evidence of calculus. Nov. 15, doing well; no trouble with micturition, urine quite normal. Nov. 24, fit for discharge: furlough and command depôt.

Case 24 (22a).—Pte. G. M., under care of Major Smith and Captain Lindsay. Shell wound, July 7, 1917. Entrance wound right buttock; missile entered rectum and passed through apex of prostate. Some urine escapes by rectum on micturition. Passed blood after being hit. Blood and pus in urine. Radiography shows foreign body 4½ inches from anterior surface of body, about level of lower end of coccyx; sectional anatomy shows it to be at level of posterior wall of bladder. July 9, cystoscopy; foreign body in bladder (*Fig.* 20); cystoscopic appearances already described in text. Running a moderate temperature of 100° to 101° in the evenings. July 11, operation; missile removed by pushing forceps through anterior wall of bladder; opening so made sutured; abdominal wall sutured except at lower end. July 18, passing nearly all urine by wound at anus; temperature going down. July 24, all urine per urethram.

Report from England.—Aug. 18, still some pus in urine. Oct. 9, urine is clear. Dec. 20, discharged permanently unfit, five months after injury.

Case 25 (23a).—Pte. J., under care of Major Maunsell. Shell wounds, July 31, 1917; scalp, thigh, and buttock on right side. Says he passed port-wine-coloured urine after being hit. When admitted to C.C.S. a catheter was passed, but no gross blood in urine; radiography at C.C.S. showed foreign body in pelvis. Arrived at base hospital, Aug. 3. Retention of urine; catheter passed; no blood; bladder sound passed; some resistance at internal meatus; no foreign body felt; bimanually nothing discovered; cystoscope passed; inner tube removed to wash out bladder; could not be replaced; attempt made to withdraw cystoscope to ascertain reason; point of instrument caught in urethra, and could not be removed; the foreign body had been caught between telescope and outer tube of cystoscope proximal to the lamp. The foreign body could be felt on under surface of urethra in front of the scrotum; cut down upon and removed; wound in urethra sutured. Foreign body measured 1 × 1 × ⅛ cm. It had evidently lodged in bladder, and caught in the cystoscope during manipulation. Good recovery.

Case 26 (24a).—Pte. J. D., under care of Major Harper. Shell wound, Aug. 8, 1917. Entrance over sacrum. Notes from C.C.S.: Gunshot wound of sacrum; metal removed from bladder; bladder sutured; drain tube to space of Retzius. Had passed urine naturally since operation. Admitted to base hospital, Aug. 9; posterior wound leaking urine; anterior wound almost healed. Aug. 12, fæcal-smelling discharge from posterior wound; some leakage from anterior wound. Reconstruction of track: sacrum, rectum, vesiculæ seminales, pelvic connective tissue, bladder. Aug. 23, leaking from suprapubic wound. Sept. 1, no leakage from either wound. Sept. 11, wounds almost healed.

Report from England.—Dec. 4, small sequestrum removed from sacral region. Jan. 5, 1918, urine cloudy, alkaline, contains pus and albumin; sinus at back of sacrum opened up and curetted. Jan. 7, urine oozing through sacral wound. Jan. 28, still in hospital, five months after injury.

Case 27 (25a).—Pte. W. H., under care of Major Everidge while at base. Shell wound, Oct. 12, 1917. Entrance right groin; no exit; track went superficial to femoral vessels, wounding vein, passed through horizontal ramus of pubis on right side into bladder extraperitoneally, then out through peritoneal aspect of bladder across rectum, tearing the gut, to lodge finally in wall of pelvis on opposite side. Admitted to base hospital Oct. 13; vomiting; rising pulse; abdomen tender in lower half, somewhat rigid, distended. About 1 oz. of urine containing blood had been drawn off at C.C.S. On arrival at base, urine was leaking through wound in groin, which was foul and gassy. Oct. 14, laparotomy; longitudinal rent about 1 in. long on peritoneal aspect of bladder sutured with two layers of catgut; transverse slit in rectum reaching to the lumen also sutured; foreign body lying in a hole in lateral wall of pelvis not removed, patient being too ill for further manipulation. Death thirty-six hours later from peritonitis.

Case 28 (26a).—Pte. W. R., under care of Major Harper. Shell wounds, Sept. 26, 1917. Peppered all over buttocks. At field ambulance, two hours after injury, vomiting, rigidity of lower half of abdomen, and tenderness, particularly on left side; hæmaturia; catheter tied in. At C.C.S., catheter removed; patient improving rapidly and passing urine naturally. Sept. 28, admitted to base hospital. Still some hæmaturia. Knee-jerks absent, band of hyperæsthesia corresponding to 11 and 12 D. Urine dribbling at times, and fæcal incontinence. Oct. 5, incontinence has passed off; wounds nearly healed; urine alkaline and contains pus and blood. Oct. 9, right epididymitis. Oct. 10, tenderness over bladder, and pain at point of penis after micturition; temperature 103°. Oct. 16, temperature falling; cystoscopy—already described in text (*Fig.* 21); two minute foreign bodies seen in bladder.

Report from England.—Nov. 4, good control of urine, but some frequency. Nov. 13, no discomfort in passing urine. Nov. 20, radiography shows no foreign body in or near bladder (they had probably been passed per urethram). Report on urine, Nov. 7: albumin nil, small number of pus cells.

Case 29 (27a).—Pte. L., under care of Major D. Crawford. Wounded Oct. 7, 1917, and lay out four days. Entrance wound just above pubis immediately to left of mid-line; exit right buttock at level of ischial spine. Oct. 13, admitted to base hospital. Urine and fæces leaking through buttock wound. Track in buttock passes into rectum. Per rectum, large hole in anterior wall at apex of prostate communicating with bladder, admitting index finger. Bladder drained through rectum by rubber tube; buttock wound also drained by tube. Suprapubic wound had entirely healed. Highest temperature 101°, highest pulse-rate 108. Marked for England Oct. 20.

Report from England.—Nov. 2, operation; some fragments of fractured right pubic bone removed. Nov. 19, a little urine per urethram. Jan. 28, 1918, still in hospital, three months after injury.

Case 30 (28a).—Pte. McF., under care of Captain Hemmans. Bullet wound, Oct. 12, 1917. Entrance wound left buttock; exit, larger in size, just below right anterior superior iliac spine. Admitted to base hospital Oct. 15. Temperature 98·6°, pulse 112; general condition poor; exit wound very septic; blood-stained urine per rectum and per urethram. Oct. 18, rigor, temperature 105·6°. Nov. 19, died.

Post-mortem.—Track from left buttock through great sacro-sciatic foramen, perforating rectum twice, bladder twice extraperitoneally, fracturing horizontal ramus of pubis and head of femur of opposite side. Pelvic cellulitis in front and to right side of bladder. Gas gangrene of iliopsoas, pectineus, sartorius, gracilis, and adductors. Acute cystitis, with necrosis of mucous membrane of bladder; this necrosis was in the form of a number of raised patches, firm, greyish in colour, and was situated chiefly on base and posterior wall. Kidneys normal.

Case 31 (29a).—Pte. W., under care of Lieutenant-Colonel Hurley. Wounded, Sept. 26, 1917, by jumping into a shell hole and impaling himself on bayonet of comrade. Sept. 28, admitted to base hospital. In great pain, lower abdomen tender and rigid; no history of vomiting; bowels had acted previous day, blood in motion; blood in urine drawn off by catheter. Examination: incised wound 1¼ in. long in outer and posterior part of left ischiorectal fossa. Laparotomy, same day, by Lieutenant-Colonel Hurley; clean-cut perforation of the antero-lateral aspect of rectum, shut off by adhesions; no gross leakage of bowel contents; wound in rectum sutured; hole in mesorectum also sutured. A clean-cut wound ½ in. long, non-perforating, on peritoneal surface of bladder; this extended as far as muscular coat; sutured. Bayonet wound was found at bottom of rectovesical pouch. Drain with split rubber tube and gauze to Douglas's pouch. Lithotomy position; perineal wound opened up, extended upwards and medially, striking inner surface of left pubic ramus, ¾ in. from mid-line. No extravasation of urine; blood-stained urine escaped freely from wound on introduction of finger to its depths; drained. Oct. 14, transferred to England eighteen days after operation, with few drops of urine still leaking from perineal wound during micturition.

Case 32 (1b).—Cpl. P., under care of Captain de la Cour. Wounded by shrapnel ball, Oct. 11, 1915. Entrance external abdominal ring on right side; missile extracted from left buttock near anus at field ambulance. Admitted C.C.S. same day; profuse hæmaturia, clots; had a large motion mixed with blood; temperature 101°; pulse 96. Admitted base hospital, Oct. 13. Temperature 102°. Abdomen tender, slightly rigid. Leaking slightly at anterior wound. Urine almost free from blood. Catheter tied in. Some ecchymosis of scrotum on right side; no swelling of testis. Gas- and fæcal-smelling stuff came through wound on right side and through catheter. Suprapubic cystostomy; large extraperitoneal cavity found, containing pus and fæcal-smelling material; pubic bone smashed at symphysis: this cavity communicated with rectum and with wound in left buttock. Oct. 17, transverse colostomy; temperature swinging to 103° in evening. Died Oct. 23.

Post-mortem.—Bladder badly lacerated; rectum opened; pubis smashed; cellulitis extended round cæcum to right renal region.

Case 33 (2b).—Lieut. M., under the care of Major Martin. Shell wound, May 2, 1916. Entrance wound right buttock, from which urine leaked. May 3, suprapubic cystostomy at C.C.S. May 16, very little urine from cystostomy wound; passing urine naturally; it contains a little pus and a fair amount of albumin. Temperature normal. No fracture. Evacuated to England doing well.

Case 34 (3b).—Pte. J. G., under care of Captain Morgan. Shell wounds, May 7, 1916. Two entrance wounds, one in right buttock and one internal to right anterior superior iliac spine; no exit. Fracture of iliac bone, complicated with severe compound fracture of both bones of right forearm and a wound of left leg. On admission to C.C.S.: vomiting; pulse 120; abdomen rigid and tender. Pure blood by catheter; swelling over lower abdomen due to extravasation of urine. Laparotomy by Captain D. C. Taylor, nine hours after injury; tissues infiltrated with urine; abdomen opened; no intraperitoneal lesion; peritoneum closed; bladder opened by suprapubic route; full of blood-clot; sponged out; laceration low down close to prostate; missile not found. May 5, amputation through arm for gangrene in forearm. Admitted base hospital, May 22. Patient pale, distressed, anxious; rapid respiration, and slight dyspnœa; had been running a high temperature at C.C.S. Urotropin given and bladder washed out. May 24, respiration rapid and difficult; sputum profuse, thick, and foul; pneumonia; urine oozing from buttock and other wounds. May 27, death.

Post-mortem.—Patches of pneumonic consolidation scattered throughout lower lobe of left lung, in places almost breaking down; congestion and some slight pleuritic adhesions at base; whole of middle lobe and upper part of lower lobe of right lung consolidated; at one part of middle lobe consolidated area breaking down; congestion at base; numerous pleuritic adhesions all over surface of right lung. Liver and spleen healthy. Kidneys: some passive congestion; pus in pelves. Track of missile passed through a series of abscesses, with purulent material in the space between them; foreign body perforated bladder twice extraperitoneally, levator ani, pelvic fascia, obturator internus, and lodged in pelvic aspect of ischial tuberosity.

Case 35 (4b).—Rfm. T. P., under care of Major West. Bullet wound, May 29, 1916. Entrance left buttock; no exit. On admission to C.C.S., condition good; severe abdominal pain and rigidity. Laparotomy by Captain Dew; nothing found but slight tear in peritoneum; per rectum, a large opening found in lower part of rectum; blood in bladder; iliac colostomy; suprapubic cystostomy; three pieces of bullet removed from bladder and one from left groin. Admitted to base hospital, June 3. Temperature 107·2°; suppression of urine; severe headache and backache; pulse 128. Later a little oozing of urine. Dry tongue. Drenching sweats after rises of temperature. Pallid. Listless; conscious. No uræmic fits. June 12, jaundiced; temperature still high; urine scanty. June 14, sordes on teeth; tremors; pulse small and rapid. June 15, died.

Post-mortem.—Pelvic cellulitis extending backwards and downwards from space of Retzius. No apparent renal trouble.

Case 36 (5b).—Pte. F. L., under care of Captain Morgan. Shell wound, June 13, 1916, right buttock. On admission to C.C.S., very collapsed, running pulse, great agony. Laparotomy by Captain Meyer; small fragment of shell found between rectum and bladder; one hole in left side of bladder; tear in peritoneal and muscular coats of pelvic colon, which was invaginated and sutured; finger passed into bladder; large foreign body found here; impossible to remove through existing hole in bladder; latter was therefore sutured; suprapubic opening into bladder; large foreign body, 1 in. long, removed; two other holes in lateral walls of bladder; impossible to suture these as patient was pulseless; bladder drained. Patient admitted to base hospital, June 20. Urine leaking from buttock wound. Evacuated to England a few days later.

Report from England.—March 23, 1917, removal of right testicle for abscess of four months' standing; both body and epididymis involved. April 12, large stone or "incrusted piece of shrapnel" removed by suprapubic route. July 5, wounds completely healed. July 11, discharge of pus from urethra; gonococci found. Patient had ear trouble which delayed his recovery. He was discharged as unfit for military service in November, 1917, about a year and five months after his injury.

Case 37 (6b).—Pte. P., under care of Major West. Wounded left buttock, June 27, 1916; nature of missile not stated. Admitted to C.C.S., June 28. Abdomen tender and rigid. Vomiting. Catheter drew off pure blood. Prevesical space opened up and found full of blood-clot; laparotomy; no intraperitoneal lesion; bladder drained by suprapubic route. On arrival at base, urine still flowing from buttock wound. July 4, death from pelvic cellulitis and sepsis.

Case 38 (7b).—Pte. B., under care of Captain Bryan. Shell wound, July 1, 1916. Entrance left buttock. Treated at C.C.S. by suprapubic cystostomy. On arrival at base, urine still flowing from wound in buttock. Corrected notes: Shrapnel wound from left hip to right iliac region; some shrapnel removed from bladder. (Shrapnel here probably means shell.—A. F.)

Report from England.—Some stricture at bladder orifice. Three stones in bladder crushed and removed. Sinus still persists from bladder to wound in right iliac region. Present condition: a good deal debilitated by prolonged suffering, etc.; is 40 years old, but appears more; has trouble with urinary sinus and often a good deal of pain. Quite possibly the stricture may give trouble in the future. Some cystitis and frequency of micturition. Recommended for discharge as permanently unfit. Sept. 9, 1917, discharged as no longer physically fit for war service, one year and two months after injury.

Case 39 (8b).—Sergt. C., under care of Major Menzies. Bomb wounds Sept. 9, 1916. Entrance left buttock; another wound in right upper extremity. No urine or fæces from buttock wound. At C.C.S., suprapubic cystostomy; metal removed from bladder; drain into bladder. Sent to base with catheter tied in. Arrived at base hospital with severe urethritis. Catheter removed. Urethra and bladder irrigated daily. Oct. 30, abdominal wound healed; voids urine normally. Nov. 4, evacuated to England doing well.

Report from England.—Urine still contained pus on Nov. 28; patient otherwise well. Posted to B.E.F., France, June 15, 1917, about nine months after injury.

Case 40 (9b).—Pte. F. H., under care of Captain Hamilton Drummond. Wounded by rifle grenade, Nov. 5, 1916. Entrance wound near middle line, 3 in. above pubis; no exit. On arrival at C.C.S. patient was in a condition of shock, and had vomited several times; a catheter drew off 10 oz. of blood-stained urine; per rectum, a foreign body, size of hazel nut, felt through anterior rectal wall. Laparotomy by Capt. Drummond; peritoneal cavity contained blood; one perforation of small intestine a foot from cæcum sutured; group of perforations 2½ ft. from cæcum; this damaged area of small gut was resected; bladder perforated almost in middle line, 1½ in. from peritoneal reflection; there was a wound of the rectovesical pouch made by the

missile as it passed through the bladder and out again ; at the bottom of this wound the missile could be felt lying on the rectum just below the peritoneal reflection ; missile removed ; finger introduced into bladder through entrance wound, and exit wound felt in the middle line behind the trigone ; Captain Drummond opened the bladder freely on its peritoneal aspect and dealt with the exit wound from within as described in text ; bladder was drained suprapubically after suture of intraperitoneal incision ; rectovesical pouch drained. Evacuated to England with small drain in bladder, doing well.

Reports from England.—Discharged on sick furlough Feb. 2, 1917. Discharged from the service on June 6, about seven months after injury.

Case 41 (10b).—A. B. McK., under care of Captain Kelly. Wounded, Nov. 13, 1916. Nature of missile not stated. Through-and-through wound from right groin to right buttock. At C.C.S., right testicle removed. Rami of pubis on right side fractured. Urine leaking continuously into wounds. Admitted into base hospital Nov. 18. Two days later pain in chest, pleuritic friction and tubular breathing at bases of lungs. Nov. 22, died.

Post-mortem.—Extensive fracture of horizontal and descending rami of pubis involving symphysis ; anterior wall of bladder torn away, hole admitted four fingers. Lymph on both pleuræ ; patchy consolidation at both bases and axillary aspect of left upper lobe.

Case 42 (11b).—Pte. R. W., under care of Major McEwen. Shrapnel ball wound, April 9, 1917. Entrance left buttock. At C.C.S., laparotomy ; a little free blood in peritoneal cavity ; large extraperitoneal hæmatoma in suprapubic region ; shrapnel ball removed from side of bladder in this area ; suprapubic cystostomy. April 21, arrived at base hospital. Abdominal wound infected ; urine flowing from suprapubic wound. April 28, leakage ceased. Evacuated to England a few days later, doing well.

Case 43 (12b).—Pte. A. V. C., under care of Captain Main. Bullet wound, April 4, 1917. Entrance right iliac region ; no exit. Missile had passed back, injuring right lateral extraperitoneal aspect of bladder, and lodged at interval between 1st and 2nd sacral foramina of left side near the bone ; large extraperitoneal hæmatoma. At C.C.S., suprapubic cystostomy. Admitted base hospital on April 11. Sloughing of scrotum. Suprapubic wound covered with phosphates. A few days later a large slough like a cast of the bladder came away on washing out the latter. May 1, evacuated to England, doing fairly well.

Report from England.—Patient up and about on July 27 ; wounds healed, but patient thin and anæmic ; frequent micturition, pus in urine. Aug. 6, improving. Still some pus in urine on Sept. 8. Oct. 22, fairly well. Nov. 15, discharged medically unfit about six months after injury.

Case 44 (13b).—Cpl. J. F. B., under care of Captain Morgan. Bullet wound, May 3, 1917. Entrance wound just to left of middle line in suprapubic region, one inch above pubis ; missile passed through anterior wall and right side of base of bladder ; exit, right buttock ; margins of obturator foramen smashed. Hæmaturia. At C.C.S., wounds cleaned and drained ; bladder drained suprapubically. May 10, on admission to base hospital, general condition poor ; patient septic, restless, incoherent ; anterior operation wound clean ; no urinary fistula in suprapubic region, but urine flowing from foul wound in buttock ; a good deal of blood-stained urine coming per urethram ; temperature 103° ; pulse 128 ; tongue coated with yellow fur, sordes on teeth ; paralysis of right sciatic nerve. May 12, *B. sporogenes* grown from blood ; gas gangrene of glutei and psoas muscles of right side ; patient a coppery colour. Died same day.

Post-mortem.—General gas infection.

Case 45 (14b).—Pte. H., under care of Captain Wilgress. Shell wounds, June 6, 1917. Entrance right buttock ; also multiple wounds of thigh and buttock. At C.C.S., laparotomy ; intraperitoneal wounds of bladder and rectum ; bladder and rectal wounds sutured ; foreign bodies removed ; abdomen closed ; suprapubic cystostomy. Name of surgeon who operated at C.C.S. not stated. June 18, arrived at base hospital. Suprapubic drain blocked, dressings soaked ; slight distention of abdomen ; slight general rigidity of abdominal wall ; bladder foul ; suprapubic wound discharging ammoniacal urine with muco-pus and gritty material ; patient collapsed and sweating ; vomiting ; laparotomy wound red, with superficial suppuration ; entrance wound in buttock discharging pus. June 23, fæcal fistula in buttock. June 26, piece of clothing and metal removed from thigh. July 4, intestinal obstruction. Major West thought the obstruction was in region of wound of rectum, and performed transverse colostomy. Death same day.

Post-mortem.—Obstruction due to adhesions between small intestine and the sutured wound in rectum ; intestines at this spot matted together ; interior of bladder foul, inflamed, and encrusted with phosphates ; the hole in bladder could not be found.

Case 46 (15b).—Pte. K., under care of Captain Palmer. Bullet wound, July 13, 1917. Entrance left buttock ; no exit. Fracture of pubic bone ; urine leaking from small wound in buttock ; bladder apparently full ; ecchymosis of abdominal wall, penis, scrotum, and perineum. Operation in base hospital same day ; attempt to empty bladder by catheter failed owing to blocking by blood-clot ; suprapubic cystostomy ; urinary extravasation ; two holes in bladder in anterior wall, one on either side of urethral opening ; that on right side led to a hole in pubic bone in which bullet was found ; perineal incision made, and perivesical space drained by

two tubes, one going towards bladder and one towards the entrance wound in the buttock where there was a collection of fluid: suprapubic wound sutured in layers, leaving an opening for a small tube which drained the bladder. July 19, suprapubic tube removed. Aug. 6, evacuated to England; temperature had been normal for a fortnight, and patient had been passing urine normally for eight days.

Report from England.—Urine leaked a little from perineum for some days, but this wound was dry on Aug. 22. Sept. 1, perineal wound healed. Sept. 15, lower end of epididymis swollen, hard, and tender. Dec. 8, urine contained much albumin and pus; frequency of micturition. Dec. 17, cystoscopy showed two small calculi in bladder; these were removed by litholapaxy, Dec 19. Note dated Jan. 7, 1918, states: "This man has made a good recovery, and will be ready for discharge from hospital in about two weeks."

Case 47 (16b).—Sergt. M., under care of Colonel Elder. Wounded by shrapnel ball, July 31, 1917. Entrance wound right buttock; no exit. Admitted base hospital, next day. Abdomen rigid; dullness in flanks; pulse 112; temperature 101°; considerable shock. Patient says he has not voided urine since injury. Catheter drew off a small amount of blood-stained urine, and a fragment of cloth was stuck in eye of catheter. Operation same day by Colonel Elder; suprapubic incision struck a large quantity of bloody fluid with urinous odour in the perivesical tissues; also free gas without fæcal odour; bladder opened, and shrapnel ball with some cloth removed; entrance wound of missile into bladder could be felt on right posterior aspect near the trigone; suprapubic rubber drain into bladder; laparotomy in right semilunar line at level of umbilicus; bloody fluid, smelling of urine, escaped; peritonitis, with exudate all over the coils of bowels; no injured intestine; abdomen closed. Temperature never rose above 101°, and pulse, which had gone up to 140 after operation, came steadily down. Patient began to pass water on Aug. 17, four days after removal of suprapubic tube into bladder. Evacuated to England, with urine still leaking from suprapubic wound.

Report from England.—On arrival at a military hospital urine was draining through wound, and patient unable to void per urethram. In the fourth week of treatment (at this hospital), one week after removal of a tube (which had been inserted after patient's arrival), patient was able to void ten ounces of urine at a time, and the bladder wound was practically healed. "There was some loss of bladder wall; much loss of fascia and muscle adjacent to wound through sloughing. Uneventful recovery; no sequelæ." Later note states that the patient joined a battalion on Nov. 29, about four months after injury.

Case 48 (17b).—Pte. K. McQ., under care of Captain Palmer. Bullet wound, Sept. 20, 1917. Entrance wound at coccyx; missile passed through rectum and bladder, and out through suprapubic region. At C.C.S., suprapubic cystostomy and iliac colostomy; coccyx injured. Oct. 18, passing most of urine per urethram; urine had leaked from rectum and suprapubic wound. Nov. 17, wounds almost healed; down for evacuation.

Case 49 (18b).—Bomb. P., under care of Captain P. N. Vellacott. Shell wound, Oct. 11, 1917. Entrance left buttock. Urine escaped from buttock on micturition. On admission to base hospital, bruising of scrotum and perineum. Captain Vellacott tied in a soft catheter. Rectal examination disclosed a foreign body on left side of middle line in front of rectum. Oct. 13, perineal section; urethra not opened; foreign body found lying against wall of bladder; opening in bladder not felt; the foreign body was large and irregular, about 1 in. long; no bone or bowel injury discovered. Catheter became blocked. Oct. 17, suprapubic cystostomy; Guyon's catheter introduced. Urine leaked from buttock and perineum. Evacuated to England, Oct. 28.

Report from England.—Nov. 2, wound in left buttock discharging fæces for first time. On Nov. 19, this had ceased. Nov. 21, passed a small quantity of urine naturally. Dec. 18, suprapubic wound dry. Dec. 20, perineal wound discharging freely. Jan. 28, 1918, patient is still in hospital,

Case 50 (19b).—Lieut. J. R. B., under care of Major Ranking. Wounded, Aug. 16, 1917, nature of missile not stated. Entrance, right groin; pubic bone fractured and spermatic cord divided; missile tore a large hole in anterior wall of bladder, and passed through sacrum. At C.C.S., ligature of cord and removal of testicle; suprapubic cystostomy. Fæces and urine from posterior wound. Sept. 2, fæces from anterior wound. Sept. 30, suprapubic wound dry, but urine still leaks from groin; urine also passed per anum. Oct. 10, passing some urine naturally. On evacuation, Oct. 11, most of the fæces coming per rectum and all the urine by rectum or groin.

Case 51 (20b).—L.-Cpl. W. F., under care of Captain Bush. Bullet wound, Oct. 17, 1917. Entry just anterior to left great trochanter. Note from C.C.S.: Bladder explored extraperitoneally; found injured; prostatic urethra completely divided at neck of bladder; blood in space of Retzius; bladder opened by suprapubic route and drained. Oct. 20, admitted to base hospital. Radiography shows fracture of ascending ramus of pubis, and bullet 1 in. behind neck of right femur. Pain in left thigh and leg (anterior crural nerve). Tender in perineum. Tube in space of Retzius not draining well. Urine very ammoniacal. Oct. 22, temperature 102°; pulse 112. Perineal section; on separating sphincter ani from bulb of urethra large space opened up, containing old blood-clot, urine, and a very small amount of fæcal matter; rami of pubis found fractured on both sides; prostate shattered, urethra torn from neck of bladder; catheter led into

bladder, and drainage tubes from each side towards rami of pubis; examination of wound of entry revealed some guttering of anterior surface of great trochanter; Carrel's tubes. Oct. 23, temperature 102°, pulse 120; patient says he is much more comfortable and free from pain. Nov. 1, died of bronchopneumonia. No post-mortem.

Case 52 (21b).—Pte. A. J. L., under care of Captain Sampson. Wounded by shrapnel ball, Oct. 4, 1917. Entrance left buttock near middle line; coccyx injured; missile perforated posterior and anterior walls of rectum, passed through peritoneal cavity, posterior and anterior walls of bladder, and came to rest beneath skin of suprapubic region, where it was found and removed. Laparotomy on day of injury; peritoneal perforation of rectum and bladder inaccessible; shut off by line of sutures across pelvic floor; drain into Douglas's pouch; suprapubic cystostomy. Oct. 6, iliac colostomy. Nov. 5, tube removed from bladder. Urine passed by natural passage about five weeks after operation. Nov. 19, admitted to base hospital. Still leaking from suprapubic wound. Cystoscopy; see text and *Fig.* 22. Per rectum, a linear oblique scar on anterior and posterior walls of rectum about a finger's length from anus. Dec. 15, fæcal fistula closed by extra-peritoneal method; sinus leading to bladder curetted. Dec. 20, some leakage of fæces. Dec. 24, suprapubic wound dry. Feb. 7, 1918, fæcal fistula almost closed; no urinary symptoms. Patient quite well.

Case 53 (22b).—Gnr. B., under the care of Captain Fletcher. Shell wound, Dec. 11, 1917. Entrance left buttock (*Fig.* 10). At C.C.S., slight trace of blood found in urine removed by catheter. Patient could pass no water during first two days. No leak from buttock wound. On admission to base hospital, no urinary symptoms. Dec. 15, urine contained albumin and blood-cells, but no pus. Dec. 23, frequency of micturition commenced; urine now contained albumin, pus in quantity, and scanty red cells; radiography showed fracture of sacrum, and foreign body 3½ in. from back on left side near middle line, at level of 4th sacral vertebra; cystoscopy has been described in text (*Fig.* 23); per rectum, thickening in neighbourhood of left vesicula seminalis. Dec. 24, suprapubic cystostomy; foreign body felt in pocket of wall of bladder; removed through bladder; suprapubic drain. Jan. 15, 1918, passed urine naturally. Has been washed out regularly with nitrate of silver solution. Jan. 28, urine free from pus. Feb. 1, out of bed; wound quite dry; no urinary symptoms. Feb. 9, evacuated to England, quite well.

Captain D. C. Taylor has kindly forwarded notes of a case recently operated on by him. They illustrate so well one type of injury and its successful management that I have thought it well to introduce them here.

L.-Cpl. M. was hit with shell, Nov. 18, 1917. Entry wound right buttock near middle line. On admission, pulse 120, abdomen rigid, vomiting. Radiography showed two foreign bodies, probably in bladder. Laparotomy: no intraperitoneal injury; peritoneal cavity closed; much extravasation of blood and urine round bladder; latter opened, and two large pieces of metal removed; bladder washed out with saline and closed; tube to space of Retzius; foreign body had entered just to left of urethral orifice, after passing through left lobe of prostate; buttock wound opened up; track found to pass through anterior and posterior walls of rectum. Patient, unfit for further operation at this time, sent back to bed and catheter passed every six hours. Twenty-four hours later, urine found leaking per anum and through buttock wound; incision in front of anus, and rectum separated from urethra; small tube inserted into track and stitched in position. Five days later tube removed. Twelve days after operation, all urine passed per urethram. One month later, patient wrote to say that all wounds were healed, and he was walking about without any symptoms.

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UNUNITED FRACTURES OF THE MANDIBLE; THEIR INCIDENCE, CAUSATION, AND TREATMENT.*

By PERCIVAL P. COLE, London.

The relative incidence of ununited fracture of the mandible as compared with other bones is difficult to assess, because, so far as I am aware, no published figures are available. From my own experience, in general military as well as in jaw surgery, I should conclude that non-union occurred more frequently in the lower jaw than in any bone of the extremities. Several factors determine the occurrence of this higher incidence: a corresponding degree of destruction in the case of the extremities would frequently lead to amputation; approximation with such loss of tissue as would give a good result in the case of a limb would result, in the jaw, in such deformity and hopeless loss of function as to render this procedure impracticable; the superficial areas of the fractured surfaces are, particularly in some situations, small as compared with that of the humerus, femur, or tibia.

The discussion of methods adopted in the ordinary routine treatment of fractures of the mandible is outside the scope of this contribution. This point is to be emphasized, in that our procedure is in important respects at variance with that advocated and practised by accredited authorities, both in this country and abroad. To define our aims is, however, not only relevant but necessary, because their validity is intimately associated with the question of non-union. There exist two schools whose views on this subject are widely divergent. The one maintains that bony union is of paramount importance; that correct alinement is incompatible with union in cases associated with loss of substance; and that therefore deformity of varying degree must not only be tolerated, but deliberately produced, to the end that bony union may be obtained. The other school is equally alive to the importance of bony union; it holds, however, that correct alinement should be determined in every case, and strongly deprecates the passive acceptance of a doctrine of deformity as theoretically unsound and practically unnecessary.

It is to be noted that this divergence of views is confined to the type of fracture associated with what is indefinitely called 'moderate loss of substance.' No difference of opinion exists with regard to fractures unassociated with loss of substance, for apart from details in the mode of treatment the question of the ultimate aim obviously does not arise. This is equally true in the case of fractures associated with such great loss that any attempt at approximation is impossible or would lead to hopeless loss of function and extreme disfigurement.

The fundamental principle that shapes the procedure of what may be termed the 'ideal' school is the restoration of the normal arch and the maintenance of accurate occlusion. It is on these lines that our cases have been treated at the King George Hospital. Stress of work has at times forced us to adopt temporary expedients, with unavoidable lapse from planned perfection. Apart from these failures, negligible both in number and degree, every patient discharged has been sent out with a normal arch and normal occlusion. The figures now brought forward have been arrived at by a careful survey of cases treated by Mr. C. H. Bubb and myself at the King George Hospital. The numbers are exclusive of cases sent to us for plastic repair and of those transferred to us from other sources with residual non-union. In a word, they are patients who have come under our care immediately or soon after the infliction of their injury.

* Hunterian Lecture delivered before the Royal College of Surgeons on Feb. 8, 1918.

We have thus dealt with 270 cases. The total of ununited fractures numbers 30, or approximately 11 per cent. Of the 30 cases, the possibility of union in 12 was absolutely hopeless, judged by no matter how exacting a standard. The resulting exclusive figure is therefore approximately 7 per cent. I maintain that these figures, apart from the means at our disposal for the rectification of non-union, are ample vindication of 'ideal' aims. Our adherence to these aims has been made known on several previous occasions. Reasons for this attitude will be indicated in considering the causes of non-un on.

In considering causation, the constitutional factor, and the presence of undue mobility, may with propriety be eliminated. Non-union is then due to :—

1. Primary loss of substance.
2. Secondary loss of substance due to necrosis.
3. Interposition of muscle, fascia, or other connective tissue.
4. Presence of a central sequestrum. This is a rare cause of non-union. There may be no other indication suggesting the presence of a sequestrum. It has occurred twice in our series. In one case non-union persisted; in the other apparently firm union gave way when subjected to normal stress.

The results produced by one or other of the first three causes are (1) fibrous union, (2) pseudo-arthrosis. Pseudo-arthrosis entails bony contact, with the formation of a true false joint, with surrounding adventitious capsule. I have only once seen anything approaching this condition, and for practical purposes it may be ignored.

Consideration may reasonably, then, be confined to the causation and nature of fibrous union. In comparing the repair of bone with that of other specialized connective tissues, one striking fact emerges. Bone differs from all other connective tissues in this important respect, that solution of its continuity is made good by the formation of a cementing substance which exactly reproduces its own structure. In the case of other tissues, irrespective of their nature, the bond of union is fibrous tissue. It is here maintained that the converse holds true—that the presence of fibrous tissue is clear evidence that the reparative process has been determined as a result of the reaction to injury of tissues other than bone. We are not here concerned with extraordinary examples of metaplasia, but with the ordinary routine phenomena that occur in the repair of connective tissue.

Viewed in this light, the name 'fibrous union,' as referring to bone, is a gross misnomer. It is a name given to a condition in which union of bone has been prevented by the interposition of the reparative products of surrounding extraneous connective tissues, or of these tissues themselves. As will be shown later, periosteum itself is included in those tissues the interposition of which constitutes the factor preventing union. It will be corroborative and advantageous to examine this view in the light of clinical and experimental data relating to the behaviour of fractures under varying conditions. The only established limit to the growth of bone is that which is determined by the satisfaction of functional demands. Bone will be laid down until equilibrium is established between functional liabilities and assets. This potential power of repair by growth has long been recognized. It has found expression in many ways, among which may be mentioned "the crystallization of the lines of force," in the picturesque phraseology of Sir Arbuthnot Lane, or the law of adaptation to function, as laid down by Wolff and Roux.

It may then be safely assumed that in the ordinary healthy individual bone possesses sufficient regenerative power to make good any defect caused by injury, provided that the conditions are such as to give the best possible effect to factors which favour the process of regeneration. These are considered to be :—

1. Prevention of interposition.
2. Restoration or preservation of that stress which is the normal stimulus to the growth of bone.

It is contended that the determination of bony union depends upon these factors, and that the successful treatment of non-union is only attained by measures designed to ensure their effective application.

A review of the fate of fractures associated or not with loss of substance will serve to determine the truth or otherwise of this contention. In the case of the ordinary fracture

without loss of substance and with little or no displacement, both conditions are determined by the contact of the bony fragments, and this without regard to the rôle of the periosteal sheath. In such a case bony union may confidently be expected. Should, however, lateral displacement occur so that the ends of the fragments overlap, union or otherwise will depend on the conduct of the periosteum. If this strips readily, the displacement will take place within an intact periosteal sleeve or bridge, and union will occur with considerable deformity. Should, however, the periosteum be densely adherent to one or other fragment, it will tear instead of strip, and so accompany that fragment in its excursion to the position of displacement. In this situation it will—together perhaps with any muscle fibres attached to it—become an interposing agent, and thus prevent union. This interposing action of the periosteum is in full accord with the rôle assigned to it by Macewen, and later confirmed by Hey Groves, as being essentially a limiting membrane to bone.

Such interposition is of particular importance in that it accounts for the occurrence of many cases of non-union of fractures of the mandible without any, or with but little, loss of substance. The facts as here cited have been verified by direct inspection of cases treated for non-union by operative measures. A large proportion of cases of non-union occur in the neighbourhood of the angle, immediately in front of the attachment of the masseter, the facial vessels being in intimate proximity. The posterior fragment is always much more difficult to expose and clear than is the anterior. This is partly due to the presence of the masseter, and partly to the greater depth of the fragment; but also to the fact that whereas the periosteum on the anterior fragment strips easily, that on the posterior fragment is densely adherent, particularly along the lower margin of the jaw. I have been able to observe on several occasions that though there had been no loss of substance—in some cases even an overlap—the posterior fragment with its attached periosteum and masseter had been carried inwards, thus determining interposition, with resulting 'fibrous union.' This condition is illustrated in *Fig.* 25.



FIG. 25.

Reverting to the question of contact, it will be obvious that a broad area of contact will not be necessary to prevent connective-tissue junction between the fractured ends, and that a very limited contact should be sufficient on theoretical grounds to determine firm bony union. This limited contact has, indeed, been found practically to suffice, a fact which has been particularly emphasized by Sir W. Arbuthnot Lane in a recent contribution on the operative treatment of fractures in war time.

The question of union in fractures associated with loss of substance depends on the amount of loss, the condition of the periosteal sheath, and the presence of comminuted bone fragments.

Clinically, primary loss of substance cannot occur with the periosteal sheath intact. Experimentally, Hey Groves has shown that, with a section of the whole bone removed and periosteal sheath intact, union rarely occurs, and is then due to the presence of bone cells adherent to the membrane and detached with it by deep stripping. It is suggested that in the cases with non-union, the periosteum played the part of ordinary connective tissue, prolapsed into the gap and united therein (*Fig.* 26). In the cases with union, the periosteum *per se* played the part of excluding connective-tissue invasion from the exterior while the bone-forming elements on its inner surface proliferated. Bony



FIG. 26.

contact there unquestionably was not. Continuity of bone-forming elements, with exclusion of alien activity, there certainly was. The beneficent part performed by the periosteum in the union of fractures is more frequently that of a membrane limiting and excluding connective tissues than a membrane limiting and including bone.

That bony union may occur with considerable loss of substance, not only in the mandible but in other bones, is clinically established beyond all doubt. In the mandible, cases have been cited by Stephens, Doubleday, and others, and many of our own cases establish the same fact. These may well be explained by the excluding disposition of the periosteum on the one hand, and by continuity of bone-forming elements attached to the periosteum on the other. The bone-forming elements may be such as to give no *x*-ray evidence of their presence, or may exist in the form of demonstrable comminuted fragments. The condition may be diagrammatically represented as in *Fig.* 27. As Sébileau has so pertinently observed: "I have seen apparently straightforward fractures, particularly at the symphysis and at the angle, preserve their original mobility for many months—some of them, in fact, did not consolidate; and, on the other hand, fractures with widely-separated fragments cicatrize by means of thick and resistant bridges of osteo-fibrous tissue in a few weeks."



FIG. 27.

It is because union cannot be guaranteed where no substance has been lost, because, conversely, union does not necessarily fail where loss of substance is considerable, and because the vast majority of war fractures of the mandible do not exhibit clean-cut loss, but rather a condition of extreme comminution, that we have from the first espoused and rigorously carried out the 'ideal' treatment.

Comminution has an important bearing on union. Clinically, it is established that such fractures, even when compound, unite in a manner that is surprising, both as regards firmness and rapidity. Hey Groves, in his experimental work, has demonstrated this fact, and made it the subject of express comment.

The remedial measures undertaken to combat non-union show clearly how predominant are the factors previously cited. Vigorous friction of the bone ends upon one another is a proceeding of classical antiquity, and is frequently attended by successful results. Success is attained in a two-fold manner. First, the fibrous junction between the bone ends is broken down by mechanical force; secondly, the real traumatic contact of the bone ends thus brought about stimulates proliferation of bone-forming elements. The narrowest bony union thus established is increased by growth, naturally evolved in response to functional demands. It is obvious that full reconstitution in such a case is a matter of time, and it is probable that many cases of so-called delayed union are capable of explanation on the lines indicated. Remedial measures, however, of this nature can be effectual only where loss of bone is small and fibrous interposition correspondingly limited.

Where loss is considerable, the only method hitherto available whereby bony continuity without deformity can be established is by a bone graft. In view of the ease with which an autoplastic graft can be obtained, and its superiority as demonstrated both experimentally and clinically, it will be unnecessary to consider grafts of the homoplastic or heteroplastic variety. That bone-grafting is established as a successful clinical proceeding there can be no doubt. This being so, it will be pertinent to determine what are or are not the essential physical properties of the graft that make for success. That this does not depend on the presumed vitality of the tissue utilized is clearly demonstrated by the work of Hey Groves and Albee. Hey Groves has testified to the fact that results similar in nature, and differing only in degree, can be obtained by the use of boiled bone. He goes so far as to maintain that "a graft of dead bone (boiled), properly fixed by metal sutures, will give a better result than a living autogenous graft fixed by catgut alone." Albee has successfully utilized grafts from bone kept in cold storage.

A great deal has been talked and written about the re-establishment on the part of

the graft of what is loosely called 'fresh vascular connections.' If this means anything, it means that through the original vascular channels of the graft blood derived from neighbouring vessels circulates anew; that the graft is nourished by such circulation in precisely the same way as before its original vascular connections were severed; and that it is as a result enabled to preserve its individual characters as a living active entity.

Considerable light is thrown on this question by consideration of the fate of free bone-grafts embedded in vascular tissues, by the results obtained on endeavouring to transplant a bony implant, and by the behaviour of free grafts of other connective tissues when used to remedy such defects as depressed scars. It has been established beyond cavil that the fate of free bone implanted into soft tissues, no matter how vascular, is gradual absorption (Phemister, Davis, McWilliams). A deliberate and conscientious attempt has been made by Imbert and Réal to remedy bony defects in the mandible by transplanting into the gap sections of bone previously implanted in the neighbouring soft tissues. Such attempts were made with the idea that the graft would be more likely to succeed after its nutrition had been definitely determined by the establishment of fresh vascular connections. They found, however, that transplantation had to be undertaken in not more than three or four weeks. If longer time elapsed, the graft was found to be so softened that effective fixation could not be attained. In all cases, the result as regards bony union was a complete failure.

A similar initial attempt of my own may be cited, undertaken at a time when my ideas on the subject were befogged by misapprehension, undoubtedly begotten of the loose phraseology employed. About eighteen months ago it occurred to me that transplantation of an implant would not only solve the problem associated with many bony defects with coincident loss of soft parts, but would permit plastic operation and bone-grafting to be undertaken at the same time. To this end a large section of the crest of the ilium, measuring twelve centimetres in length, was implanted in the neck of a patient whose chin had been shot away together with the greater part of the body of the jaw. Owing to a severe hæmatemesis from which the patient nearly died, further operation was indefinitely postponed. Originally the bony mass formed a prominent projection in the neck. Its removal was decided upon owing to its marked and progressive diminution in size, and when removed a few weeks ago it was found to be, at most, one-fifth of its original bulk.

Further light is shed upon this question of vascularity by observations as to the fate of free transplants of other connective tissues utilized to make good defects of the soft parts. This measure is one that clinical experience has shown to be successful. I first employed musculo-fascial grafts as a means of filling out deforming depressions on the face. Fat grafts have been used in the same way. Acting on the false assumption, as I now hold, that these grafts established fresh vascular connections, it seemed reasonable to suppose that a small area of skin might be included in addition to the fatty and aponeurotic tissues. If structures on which skin depends for its nutrition were included, and if such structures became vascularized from the bed in which they were implanted, then surely the skin should live. The time factor was considered, but the hardihood of skin is notorious: the growth, even, of hair long after body death has occurred is testimony to this effect. The result was curious. For the first few days, except that the implanted skin was somewhat blue, all seemed well. This blue tinge is frequently seen in pedicled flaps, and was not, therefore, regarded as of specific importance. Gradually the blue deepened, a curious 'bogginess' became apparent on palpation, and finally the whole area became black, but no suppuration occurred. The whole mass was firmly held, the outer surface quite dry. Shrinkage gradually occurred, but there was no attempt at exfoliation. It was evident that in this case there had been no establishment of fresh vascular connections, and in the light of it other cases were examined more carefully. It was found that shrinkage had occurred, and that the area at the site of implant had assumed a hard inelastic consistency quite foreign to the substances implanted. It was impossible to conclude otherwise than that these free implants had been absorbed and

replaced. To what extent, if any, cellular proliferation had taken place in the graft, it was impossible to determine, but the ultimate result appeared certain.

Consideration of the results obtained by the use of free transplants of soft tissues leads then to the conclusion that these are absorbed and replaced, a view confirmed in the case of muscle by Serafini. Additional evidence is afforded by the fact that results equally successful have been obtained by the use of decalcified bone. The use of this devitalized absorbable material in the plastic surgery of the soft parts is exactly comparable to the use of boiled bone to remedy a bony defect Bone, then, behaves like other vascular connective tissues, and shares a like fate when transplanted into the soft parts. The cutting off of the blood-supply to such tissues leads to death in mass of the part affected. Death so occasioned rarely occurs in the body apart from septic processes, or occurs in such situations as lead at once to the introduction of septic factors. The only instance analogous to the condition of a free aseptic graft is that of infarction. Adami thus describes the resulting processes : " The central dead area becomes the seat of a progressive formation of granulation tissue. New capillaries pass in from the surrounding vessels and become clothed with fibroblasts until a new connective tissue completely replaces the dead tissue, and then, after the nature of new connective tissue, undergoes pronounced contraction, so that the end-result is the production of a dense depressed scar of firm connective tissue."

It is contended, therefore, that the establishment of fresh vascular connections is invariably determined as the result of an inflammatory interaction between tissues themselves possessed of active circulation. Bleeding has been noticed on section of a free bone graft when exposed some time after implantation ; injection of the limb has succeeded in showing in an inserted bone graft vascular channels obviously derived from the systemic circulation. This blood and these blood-vessels are, it is maintained, derived from and confined to the invading tissues. Obviously there is a profound difference between vascularization by invasion and vascularization by intercommunication.

That a fractured graft has shown evidence of union by bony callus is brought forward as incontrovertible proof of the vitality of that structure—proof, in other words, of vascularization by intercommunication. This phenomenon is, however, susceptible of quite another explanation. Invasion from the freshened bone end would occur, as diagrammatically shown in the upper diagram in *Fig.* 28. Fracture of the graft will liberate these invading elements, as shown in the lower diagram. Callus will be formed from the liberated contents of the graft, and not at all from the graft itself.

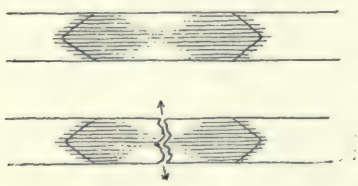


FIG. 28.

But, such happenings duly considered, there remains the fact that bony continuity can be determined by means of a bone graft, provided the graft is in suitable contact with the separated ends of the fragments. Davis has shown, however, that if one end only of the graft is in contact with living bone, the same result ensues as if no such contact was established. A bone graft only succeeds in determining the growth of bone when it is in intimate contact at each end with living bone, a structure the inflammatory products of which have the specialized function of reproducing a like tissue from which they emanated, as previously noted.

It is this intimate contact with living bone which dominates the whole field of bone-graft surgery ; it favours invasion of the graft by bone-forming elements derived from the living mother bone, and at the same time restores to the separated ends that stress which is the natural stimulus to the proliferation of such elements. Osteogenesis is favoured by the stress imparted by the graft to the mother bone, and not by that imparted by the mother bone to the graft. This view is alone reconcilable with the known fate of a graft implanted in soft tissues only. To reason that in the latter case atrophy takes place because the graft is functionless, implies a prescience on the part of that structure that the most rabid teleologist would hesitate to invoke. It would appear that bony continuity is established

by a process aptly termed 'creeping substitution,' and it is tentatively suggested that this process is somewhat analogous to that which occurs in the regeneration of nerve fibres following suture of a divided peripheral nerve. As regards the relation of the graft to the soft parts, it may be safely deduced from what has previously been stated, that the bone graft succeeds not because of any action of the soft parts upon it, but because of its action upon them, In other words, it prevents by continuity of mass the junction and organization of connective-tissue products in the gap. That continuity of mass is essential to success is shown by the fact that the insertion of fragmented bone does not determine union. This has been experimentally demonstrated by Hey Groves, who expressed surprise at the negative result obtained. Bone dust was found to be even more ineffectual. These findings are completely at variance with the vascular theory, confirmatory evidence of the truth of which would have been afforded by an exactly opposite result; smaller fragments must obviously be more easily vascularized than large.

It is clear that the introduction of such a devascularized body as a free bone graft into a septic environment will probably lead to its extrusion as a septic sequestrum. The first essential of the soft connective-tissue bed is, therefore, that it shall be free from frank or concealed sepsis. All that is required in addition is that the tissues shall be sufficiently pliable to permit nice adaptation of the graft, and sufficiently well nourished to maintain their vitality when sutured, and thus prevent the introduction of sepsis from without.

The bone graft, then, succeeds because it is permeable and absorbable; because it is enabled by continuity of mass to prevent organization of non-bone-forming connective tissues in the gap; and because it restores the stimulus of stress to the separated bone ends by virtue of its solidity. It succeeds, in a word, by establishing exactly those conditions which have been shown to be necessary for union in the case of all fractures, with or without displacement or loss of substance.

No mention has been made of the periosteum, because the presence of this membrane is not essential to the success of a graft. Davis, in the course of an experimental investigation to determine the relative permanence of free transplants of cartilage and bone, found that bone covered with periosteum was absorbed much more slowly than when stripped of this membrane. It would appear that periosteum included in a free transplant opposes an additional barrier to connective-tissue invasion, and with that view its preservation is indicated.

The attainment of union is undoubtedly important in so far as it fulfils a functional demand. There is, however, no academic virtue in union apart from this, and therefore the ultimate and only test should be a functional one: in the case of the mandible, the patient's ability to masticate ordinary foods. *X*-ray photographs will not supply this necessary information. Indeed, subjective must take precedence of objective signs, though the latter may determine a strong prima facie case. It is precisely this personal factor that renders the measure of functional disability so difficult to estimate. That non-union, used in the strict sense of the term, is not incompatible with perfect function is as certain as that in some cases of obviously sound bony union the ability to masticate hard foodstuffs is denied. Functional disability varies according to the site of the fracture. In the ascending ramus, the nearer the fracture to the condyle the less is the disability occasioned. Complete loss of the ascending ramus ,properly treated, gives rise to no functional disability whatever, as is evidenced by a case at one time under my care and now discharged. In the horizontal ramus, the disability increases the nearer the site of fracture approaches the symphysis. In general terms it may be stated that if both the masseters maintain attachment to one fragment, disability is relatively slight.

This functional estimate is obviously of importance from the point of view of treatment. It will be the deciding factor in determining the advisability of endeavouring by open operation to make good the functional defect. The extent of the functional defect and the improvement likely to follow operation should be duly considered. The operative result would appear to be somewhat of an unknown quantity. This is due partly to the distrust of such procedures which many dental surgeons display, and partly to the

detached attitude sometimes assumed by surgeons in charge of such cases. The attitude of the surgeon fosters the distrust of the dentist, who tends to adopt ultra-conservative measures, content to suffer present ill rather than adventure worse to follow. Progress in this, as in many other, issues associated with war injuries of the jaw and face, has been retarded by lack of proper collaboration between surgeon and dentist.

An endeavour will be made to present a fair, unbiassed account of cases of non-union coming under the joint care of my dental colleague, Mr. C. H. Bubb, and myself. The methods employed have been as follows :—

1. **Plating.**—(*a*) Plating alone; (*b*) Plating with interposition of fragmented bone.

Two cases have been dealt with, the lesion in both being non-union of a fracture of the ascending ramus. In the one case there was but little loss of substance; in the other the gap, after trimming the bone ends, was one and a half centimetres. Both cases were splinted, and no attempt was made to establish contact.

In the first case, a two-holed silver plate was used. The operation was done on March 9, 1917. The plate has not been removed, and gives no trouble. The use of a two-holed plate was mechanically unsound. Functionally, the patient is greatly improved. Seen on Nov. 2, he stated that he could eat crust if not too hard, and meat if not gristly. Partial success only is claimed for this case.

In the second case, a four-holed silver plate was used, the gap being strewn with bone fragments detached from the angle of the jaw. The plate was removed, not because it gave trouble, but because it was hoped that further consolidation might occur. As regards union, this case is a complete failure. Functionally, his occlusion is perfect (he has an almost complete set of teeth) ; there is little or no deviation on opening the mouth ; his direct bite is powerful ; but the grinding movement is considerably impaired.

Plating has a very small sphere of usefulness in ununited fractures of the mandible, owing to the fact that necessary contact cannot be secured without traction. Wire is difficult to use with fractures of the ascending ramus, owing to the fact that the deep aspect of the fragments is so inaccessible. It is an open question whether fractures at or above the middle of the ramus are not better left alone. If operation is decided on, a bone graft should be used if the defect is considerable. If the defect is very small, contact should be established by the plate-wire method described later.

2. **Wiring.**—(*a*) Buccal cavity opened ; (*b*) Buccal cavity not entered.

It sometimes happens that in cases of old mal-union with considerable deformity, the only possible method of dealing with the fragments is to wire them immediately. The mouth cavity is necessarily opened in the course of reduction, but the risk in such a case is worth taking. Only once, in my experience, has such a course been necessary. The wire was removed subsequently. The functional result is perfect.

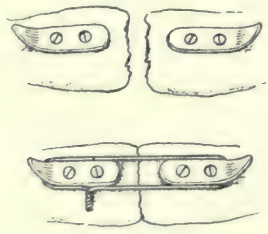


FIG. 29.



FIG. 30.

Cases suitable for wiring by the ordinary aseptic technique are those in which there is little or no loss of substance. As has been pointed out, these fractures occur in the neighbourhood of the angle. The posterior fragment is left free. The anterior fragment, if not edentulous, is splinted in correct alinement. When the lower jaw is edentulous no splint is used. Cases have been treated in this way with consistent success. Where wiring is practicable, success may reasonably be regarded as certain. The difficulty in wiring is to avoid opening the mouth while clearing the deep aspect of the fragments to permit the passage of drill and wire. I have lately devised and used a combined plate and wire method, the mode of application of which is illustrated in *Fig.* 29. The plates are first screwed into the fragments. The wire is then passed under their upturned outer ends. Traction on the wire brings the fragments into contact, and the wire is then twisted. *Fig.* 30 shows the plates and wire *in situ*.

3. **Bone-Grafting.**—(*a*) Free autoplastic graft ; (*b*) Pedicled graft.

The position of the bone graft is the most vexed of all the problems associated with fractures of the mandible. Little enough has been written as to the success attending the use of bone grafts to remedy defects in the long bones. Still smaller are the available data with regard to its application to the mandible. Albee claims 100 per cent of successes, but his work is largely concerned with the treatment of recent fractures and the correction of spinal deformity. It is quite certain that nothing like this proportion of successes can be claimed when the object in view is the reconstitution of a bone which has suffered loss involving its whole thickness. As regards the mandible, the scantiness of effort, or at least the scantiness of success, may be judged by consulting the records of recent meetings. At the annual meeting of the British Dental Association in London, June, 1916, a special session was set apart for the consideration of this subject. No opening paper was read, because no one could be found willing to undertake the task. At the Medical Society of London, in December, 1917, the question was dealt with in a general way by Captain Kelsey Fry, but no details were given such as might lead to the estimate of results. This is scarcely to be wondered at when it is considered that only three or four out of one hundred cases with fractured mandibles either demand or are suitable for a bone graft, and also that months must elapse before the final result can be estimated. Eve reported five cases without indicating the results obtained. McWilliams, reporting six cases, urges that repeated operations may be required, and should be persisted in till the desired result is attained ; with that view I heartily agree. Lindemann has published a series numbering no less than 282 ; this colossal contribution suggests that the writer must have access to an enormous number of patients, or that the percentage of non-union must be very high. So extensive is the ground covered, and such is the time required to treat effectively the numerous lesions grouped under the heading of war injuries to the face and jaws, that concentration as regards cases of non-union might well be resorted to with good results.

There are certain peculiar difficulties associated with grafting in fractures of the mandible. The exposure of the fragments is always attended with a certain danger of opening the mouth. This danger is, I think, exaggerated. It has only happened to me once, and the operation was then promptly abandoned. The relatively small size of the bone, especially in old fractures, and the necessarily restricted area in which to work, are difficulties much more formidable. Elaborate dovetailing is practically impossible, and I feel sure that people who reproduce diagrams illustrating such a procedure can never have attempted the operation on the living subject.

The necessity for the employment of a free graft presupposes loss of tissue of some extent. Such loss is frequently associated with coincident damage to the soft parts, with the formation of a buccal fistula of varying dimensions. The possibility that a graft may be required must be borne in mind from the time treatment is begun. The necessary plastic operation must first be performed. This includes closing the fistula and elevating the soft parts, to prevent their adhesion to the bone in the neighbourhood of the gap, and to provide a sufficient thickness of soft parts to accommodate the graft. The procedure will best be illustrated by the consideration of a concrete case. *Fig.* 31 shows the condition

of a patient immediately before the plastic operation was undertaken. A suitable splint was adapted to retain the fragments in correct position. A wide exposure of the area was then obtained by free reflection of the soft parts. The ends of the fragments were



FIGS. 31 and 32.—Patient before the plastic operation and after recovery from plastic operation, and before insertion of the graft.

exposed, and the mucous membrane of the floor of the mouth was dissected up and united to the mucous membrane of the cheek. Under cover of this the bone ends were shut off from the buccal cavity, and between them was inserted a piece of decalcified bone. The soft parts on the outer aspect of the bone were brought together in such a way as to raise the corner of the mouth. Counter-drainage through a stab wound was estab-

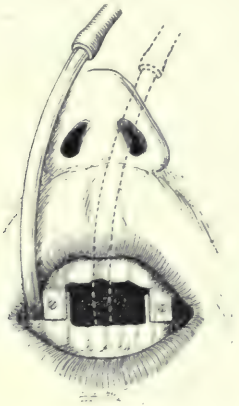


FIG. 33.

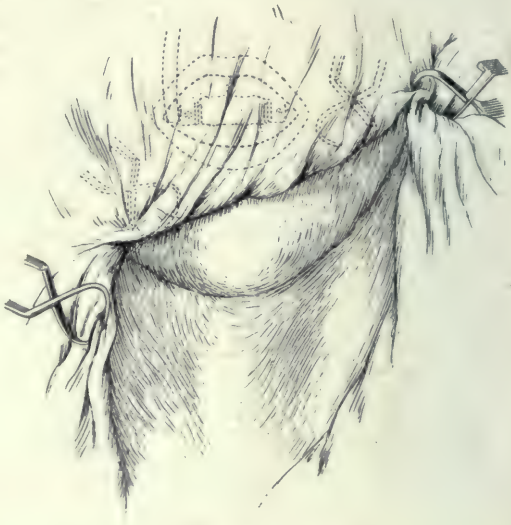


FIG. 34.

lished. The parts healed uneventfully. Nutrition was promoted by radiations and massage, and the patient is now ready for the insertion of the graft (*Fig.* 32). In order to eliminate the possibility of infection from latent sources of sepsis an interval of three months is allowed to elapse in such a case before the grafting operation is undertaken.

The technique of this operation is as follows: Two or three days previously, upper and lower cast-metal cap-splints are cemented in place. These splints are provided with bilateral overlapping threaded flanges which, when fixed together by screws, determine the position of the fragments in correct alinement (*Fig.* 33). When the patient is on the operating table these screws are removed, allowing the mouth to be freely opened for the passage of the intratracheal catheter. As soon as the catheter is passed, the screws are replaced. It will be noticed that the jaws so disposed are in the open bite position. This position is essential if intratracheal methods are employed. The anæsthetist is then isolated from the operation area (*Fig.* 34). A curved skin incision extending well into the neck is now made, and a flap turned up to expose the site of the fracture (*Fig.* 35). Bleeding vessels are ligatured and towels clipped to the skin margins. The ends of the fragments are then exposed, cleared, freshened, and shaped for the reception of the graft (*Fig.* 36). The graft, taken as a rule from the tibia, is now cut, the length and shape being determined by the use of calipers and a pattern cut in sheet lead. The plates are screwed to the graft before the detaching cross-cuts are made (*Figs.* 37, 38). The graft with detached plates is then transferred to its destined site and fixed in the gap by two screws attaching each plate to the corresponding fragment of the fractured mandible (*Fig.* 39), and the wound sewn up (*Figs.* 40, 41). A similar technique is adopted when rib is employed (*Figs.* 42, 43).

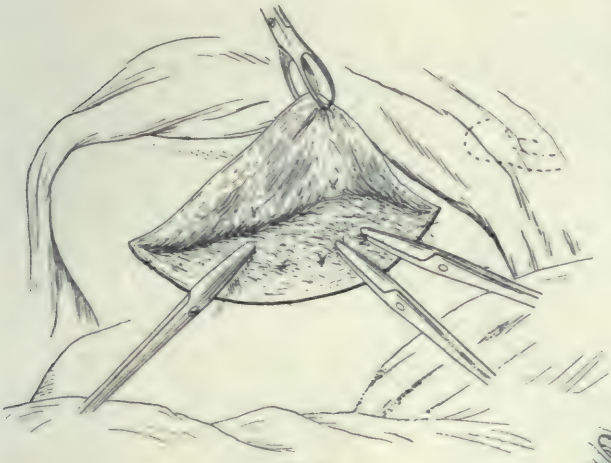


FIG. 35.



FIG. 36.

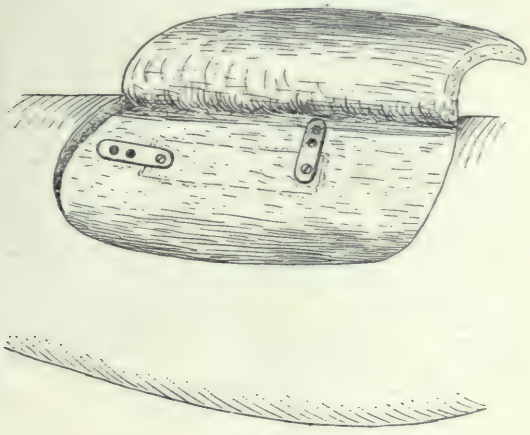


FIG. 37.

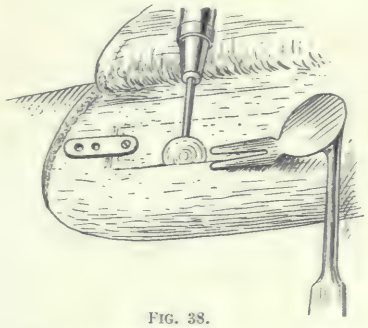


FIG. 38.

We have always acted on the assumption that fixation of the fragments and fixation of the graft are conditions essential to success. A considerable experience in the operative treatment of fractures of the long bones by metallic fixation entirely negatives the view

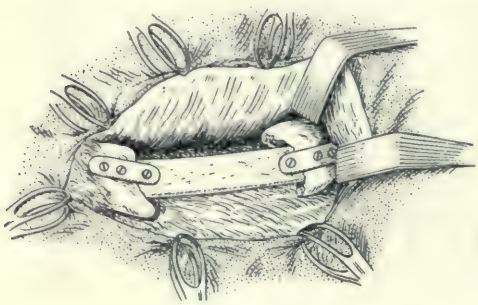


FIG. 39.

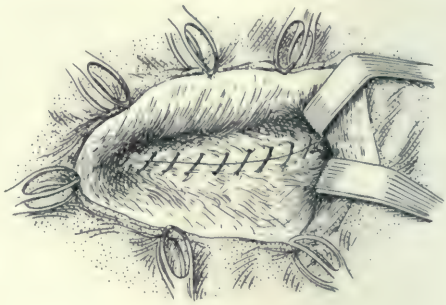


FIG. 40.

that any serious impediment to osteogenesis is occasioned by metal used in this way. This view is strongly supported by Sir W. Arbuthnot Lane and Major Hey Groves. The latter, in his Jacksonian Prize Essay, concludes as regards the reaction of living bone to metallic suture or pins, that "the living bone is not prevented from osteogenesis by their presence."

Hey Groves also maintains that absorbable ligatures afford no fixation in the real sense of the word, becoming softened in a few hours and yielding to any strain. With these conclusions my own experience is in entire accord.

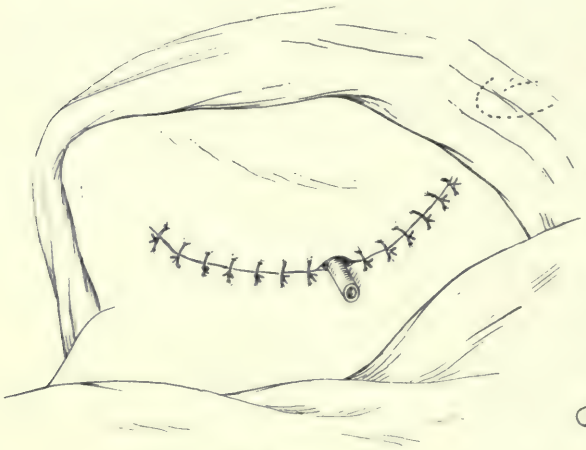


FIG. 41.



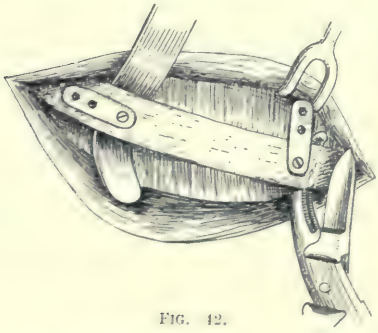


FIG. 42.

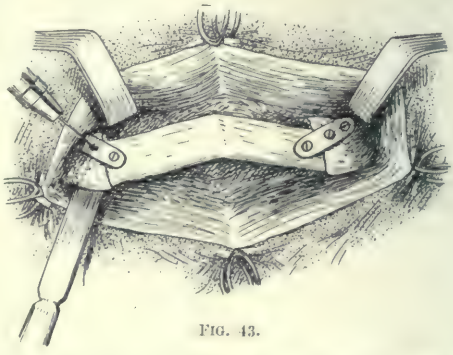


FIG. 43.

Efficient fixation there must be. If it can be attained by means other than the use of metal plates or wires, so much the better. In certain situations and under certain

conditions it is possible to fix a graft by wedging, with the assurance that such fixation will be adequately maintained. There are, however, a large number of cases in which such fixation is totally impossible. It will be shown that the success of the graft is in no wise jeopardized by the use of metal plates.

The procedure as regards the treatment of the periosteum has varied. Where tibia has been used, no attempt has been made to preserve the periosteum. On the rare occasions when a rib has been deemed more suitable, the periosteum has been retained on the outer aspect. As far as is known, no difference in behaviour has been determined by the presence or absence of this membrane.



FIG. 44.

Ten cases have been operated on by the use of free grafts in the manner described. The length of the graft has varied from 2½ to 7½ centimetres. In two cases suppuration occurred with subsequent extrusion of the whole graft. In both cases insecurity of fixation was the causative factor. In one case the electric motor broke down, necessitating the use of the hand drill; the splint was thereby strained to such an extent that in a few days it gave way, thus allowing free play to the previously fixed posterior fragment. Even in these cases, however, the area of the gap has been considerably diminished by the growth of a new bone. In one case wiring has been rendered practicable, as I know from direct inspection of the fragments. The other case can now be dealt with by means of a pedicled graft, owing to diminution in the size of the gap. In three of the remaining eight cases localized infection has occurred. In one the tissues overlying the graft were very badly nourished, and a sinus developed several weeks after operation. In the other two cases lobules of the parotid were wounded in exposing a very deeply placed posterior fragment; salivary fistulæ with inevitable infection occurred; in neither case has infection determined failure.



FIG. 45.

In three of these cases sufficient time has elapsed since operation—ten to twelve months—to permit a just assessment to be made of the results obtained. Of five cases, then, whose fate is known, three have been completely successful. Of the remaining five, progress has been such, as compared with known successes, that at the very minimum a percentage

success of 60 is assured. It must be emphasized that the failures occurred in the earliest cases, and are ascribable to known causes. Every case subjected to grafting has been one presenting a condition of floating non-union, and no selection whatever has been exercised.

Figs. 44, 45, 46, are characteristic *x*-ray photographs showing the condition before, during, and after treatment; the plates were removed as soon as bony continuity had been established. In *Fig.* 47 another case is illustrated; firm continuity has been established, with a perfect articulation; the patient has been discharged with plates and screws *in situ*.



FIG. 46.

Pedicled Grafts.—It is obvious that the use of free grafts is open to many forceful objections. The graft consists of a devascularized fragment; its exact mode of action is for this very reason not definitely settled, in spite of all endeavours at elucidation; for this reason, too, it is peculiarly susceptible to sepsis. The employment of bone possessing its own independent blood-supply is infinitely preferable on practical and theoretical grounds. Theoretically, because no doubts can arise as to its mode of action. Practically, because results will be more certain and more rapid. These advantages will accrue provided coincident disadvantages do not outweigh them. The pedicled graft has been employed in the case of the limbs, and occasionally to make good defects in the jaw. In the latter case, clavicle, sternum, and rib have been utilized, the pedicle being planned according to the source of the graft and the position of the defect. In addition, small fragments of the jaw itself pedicled on periosteum have been employed; it is obvious that the applicability of this procedure must be very limited, and it scarcely deserves to rank in the category of pedicled grafts. Owing to technical and other difficulties, these operations have not found favour. Hey Groves, discussing this question, says: "In general terms it may be said that these elaborate pedicle operations are obsolete. They all involve very grave disadvantages."



FIG. 47.

The appeal of the pedicled graft, however, as a sound surgical measure cannot be denied. My attention had been constantly directed to the remarkable way in which union occurred in comminuted fractures of the mandible. Particularly striking were a series of cases in which a large fragment of the basal margin was apparently completely detached. So consistent were the results, that union could confidently be predicted in such a case even when considerable loss had occurred in the overlying parts of the bone. A consideration of the anatomy of this portion of the bone (or, to be accurate, that portion lying in front of the masseter) showed that to its lower

margin was attached the deep cervical fascia, to its outer surface the platysma, to its inner surface near the symphysis the anterior belly of the digastric. It seemed clear, both on clinical and anatomical grounds, that this portion could be detached and utilized as a pedicled graft. The first operation carried out on these lines was performed in June, 1917. The feasibility of the procedure was clearly demonstrated. Other operations of this nature have followed, and improvements in technique have been evolved. Months must elapse before errors are demonstrated, and before it can be determined whether or not remedial measures have succeeded.



FIG. 48.

In my first cases, contact between the pedicled graft and the freshened fragments was maintained by absorbable sutures, first catgut and then kangaroo tendon. It was found that union of the graft with the posterior fragment had failed owing to the pull of the muscular pedicle. In three cases exhibiting this defect the fracture area has been again exposed. Union of the graft with the anterior fragment was so perfect as to escape detection. Posteriorly, fragment and graft were separated by fibrous tissue. The graft and fragment were refreshened and wired together (*Fig.* 48). It is obvious that a secondary operation of this nature must diminish the chances of complete success.



FIG. 49.

To remedy this error in technique, contact is now maintained by means of silver wire. The procedure is as follows. The skin incision is made extending well into the neck, reaching a lower level in front than behind (*Fig.* 49). A flap consisting of skin only is raised to the requisite level. The posterior fragment is thoroughly exposed. The extremity only of the anterior fragment is exposed, so that the extent of the gap may be gauged. An incision is now made through the soft parts clothing the outer aspect of the anterior fragment, at a level immediately below the buccal sulcus. The basal margin of this portion of the jaw is then sawn off (*Fig.* 50). The periosteum on the inner aspect of the fragment is incised. Lateral incisions through platysma and deep fascia are made to define the pedicle, which is then gently dissected from the underlying structures. The graft is thus freed to an extent sufficient to allow easy adaptation in its new position. The posterior fragment is now freshened to provide as broad a surface of contact as possible.

Anterior and posterior fragments are then drilled for the passage of a fine silver wire (*Fig.* 51). The wires are passed through the pedicle, surround the graft, and, when tightened and twisted, ensure snug contact between graft and freshened fragments (*Fig.* 52). The soft parts are brought together with a few catgut sutures, and the skin sewn up (*Fig.* 53). A drainage tube is inserted and retained for twenty-four hours. *Figs.* 54 and 55 illustrate a case thus dealt with. It is scarcely necessary to add that the same type of splint is utilized as for a free graft.

The employment of such a pedicled graft to remedy defects in the mandible is, so far as I am aware, an entirely novel procedure. I have succeeded in thus detaching a thick

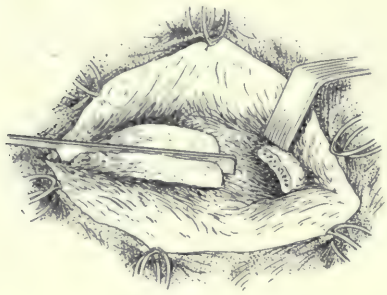


FIG. 50.



FIG. 51.

well-nourished bone fragment, measuring 3½ centimetres in length. The vast majority of ununited fractures occur on the lateral aspect of the mandible, and rarely exhibit a gap exceeding 3 centimetres in length. This operation, then, enjoys a wide range of applicability, and constitutes, I submit, a considerable addition to the methods of treatment at our disposal. I have not as yet employed bilateral pedicled fragments as a means of remedying non-union at the symphysis, but shall certainly do so when occasion arises. Free grafts are now used only in cases where the gap is too wide to be bridged by a pedicled graft.

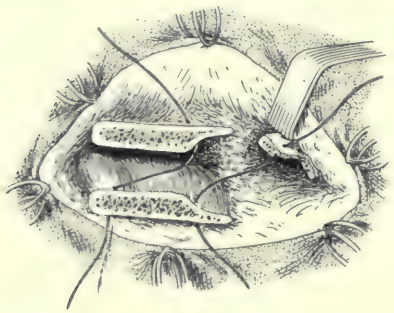


FIG. 52.



FIG. 53.

Eight cases have been dealt with in the manner above detailed. In four of these absorbable sutures were employed, and three of these, as before stated, needed a second operation. In the last four cases contact was maintained by wire sutures. In one only has there been the slightest trace of sepsis. In this case some latent source of sepsis must have been encountered inadvertently. Considerable swelling occurred, with discharge of blood-stained pus into the mouth, soon followed by the subsidence of all symptoms. The wound in the neck was not affected.

The results obtained by this method are rapid and certain. To such an extent is this so, that in cases with non-union amenable to treatment by means of a pedicled graft success can be practically guaranteed. The first case of the series is not claimed as a complete success, but the causes of failure, as before noted, have been recognized and remedied.

The results obtained by the operative treatment of non-union may be concisely summarized thus. There were 30 cases* subjected to operation; in 2 of these the operation was abandoned as impracticable. Of the remaining 28 cases, 10 have been operated on too recently to permit of any definite statement as to the results obtained. Of the 18 cases whose fate is known, 13 have been completely successful, 2 considerably improved, while the other 3 must be regarded as failures. It will thus be seen that the successes are over 70 per cent.

There has been no mortality, and post-anæsthetic complications have been entirely absent. In all but two cases ether has been administered by intratracheal insufflation, and the uneventful convalescence is entirely attributable to the skill exhibited in administration by Dr. Francis Shipway and Mr. Ramsey Phillips.



FIG. 54.

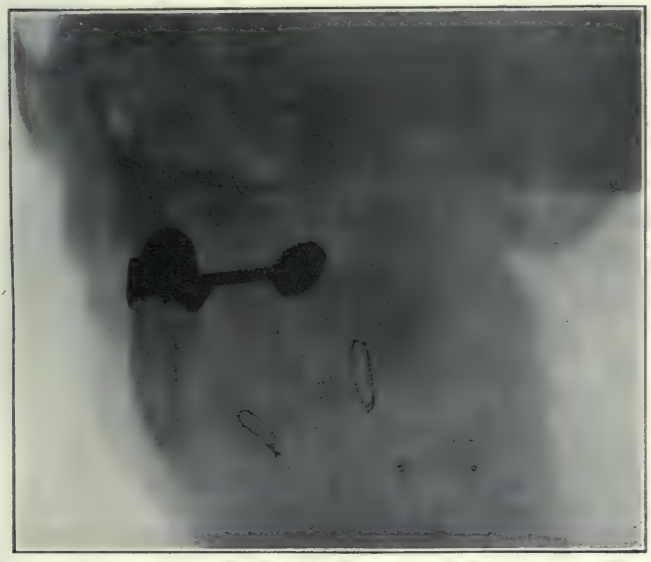


FIG. 55.

The results are such, in a word, as to justify the conclusion that no patient so afflicted should be discharged until operation has not only been offered to but urged upon him. The functional disability associated with ununited fracture of the mandible is an unnecessary disability in most cases. It is a blot upon the escutcheon of surgery which we, if we be worthy devotees of the art, must determine to remove.

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THE TREATMENT OF GUNSHOT WOUNDS OF THE FACE ACCOMPANIED BY EXTENSIVE DESTRUCTION OF THE LOWER LIP AND MANDIBLE.

By Major V. H. KAZANJIAN, Harvard Surgical Unit,
and Captain HAROLD BURROWS, R.A.M.C. (T.F.)*

Many problems arise in the treatment of gunshot wounds of the jaws. Not the least perplexing of these confronts the surgeon in a case in which the greater part of the body of the mandible has perished together with the lower lip, chin, and sublingual tissues (see *Figs.* 59, 66, 73). Such cases are not frequent; nevertheless it may be worth while to consider the means by which the victim of such an accident may yet be rendered an efficient individual.

We may describe the treatment under three headings, which approximately represent three successive stages in the management of any case: (1) *Early treatment*; (2) *Re-establishment of the mandibular function*; (3) *Restoration of the lower lip and chin.*

1. **Early Treatment.**—Our first care will be concerned almost entirely with preserving the patient's life, and meeting the various early complications which may arise. Shock calls for no special comment; it is treated as in other major wounds. Primary hæmorrhage is not in itself a great menace in these cases, for the vessels injured are terminal and not of large size, while the wound is widely open from the first. Secondary hæmorrhage is uncommon for similar reasons; when it does come about it is not profuse, and is easily checked by securing the bleeding vessel in the open wound. Local sepsis, though it may be severe in the early stages, as a rule subsides rapidly with suitable attention. Sustained pyrexia is rare, unless secondary complications have developed in the lung or other organs.

Certain special dangers, peculiar to the cases, are met with, and they call for remark. The first of these is respiratory obstruction. Two factors are involved in its production. The first and less important is traumatic œdema of the tongue and glottis. The second, and principal one, is the absence of the body of the mandible, for this entails the loss both of the anterior attachments of the tongue and of the elevators of the larynx; the consequence is that, if the patient be supine, the tongue falls back, the larynx is tilted backward, and the glottis becomes obstructed. The immediate treatment is to raise the patient into a sitting posture with the head well forward, and this simple manœuvre will often be sufficient to bring about instant relief. If it fails, tracheotomy must be done without delay. This respiratory difficulty, and the means by which it may be relieved, must be borne in mind throughout, for if a general anæsthetic be given to the patient for any purpose acute dyspnœa is almost sure to result. In such an event time must not be wasted in fruitless attempts to provide a sufficient air-way by pulling forward the tongue, for this by itself will fail. The postural treatment must be adopted at once, and if it does not succeed immediate tracheotomy must be done.

Another peril to the patient with an infected wound of the mouth is the inhalation of septic material into the air-passages, with consequent bronchopneumonia. This complication has a heavy mortality rate, and in our experience it is almost always attributable to the administration of a general anæsthetic. For this reason, and also on account

* We desire to express our indebtedness to our colleague, Captain F. Brigham, R.A.M.C., of the Harvard Surgical Unit, for kind assistance in preparing this paper.

of the liability to respiratory obstruction which has been mentioned already, we think it should be a rule never to give a general anæsthetic to one of these patients unless the nature of the case renders it imperative; in such a case, precautions must be taken to forestall the inhalation of septic discharges. Briefly stated, the precautions we employ are the reduction of salivation by means of atropine given hypodermically, administration of the anæsthetic by nasal tubes, and thorough packing of the buccal cavity with dry gauze.

Apart from urgent complications, the amount of surgical interference required in the early stages will be small, and will be limited to the removal of dirt, loose fragments of bone, teeth, and roots. A little later, when the wound begins to show healthy granulations, a certain amount of early secondary suturing may be done. This will be effected under local anæsthesia, and will be limited to sewing up the outlying radiations of the wound, and closing as much of the main wound as may be done without impeding drainage.

With regard to dressings, there is not much to be said. The wound is widely open, and is continually washed with abundance of the patient's own saliva. This necessitates frequent changes of dressing, and on each of these occasions the mouth is syringed out with antiseptic solution, usually Listerine or a solution of potassium permanganate.

The feeding of these patients calls for a few words. Owing to the loss of the anterior attachments of the tongue, as well as to the absence of the lower lip, the patient is unable to swallow in the usual way. Food must therefore be given with a nasal tube, and it must be administered in large amounts. When nasal feeding is impossible on account of obstruction of the nares, a small-calibre soft œsophageal tube is necessary. It is desirable, however, to use the nasal tube whenever this is possible, for its introduction is less unpleasant for the patient, while it avoids thrusting septic discharges from the mouth into the fauces.

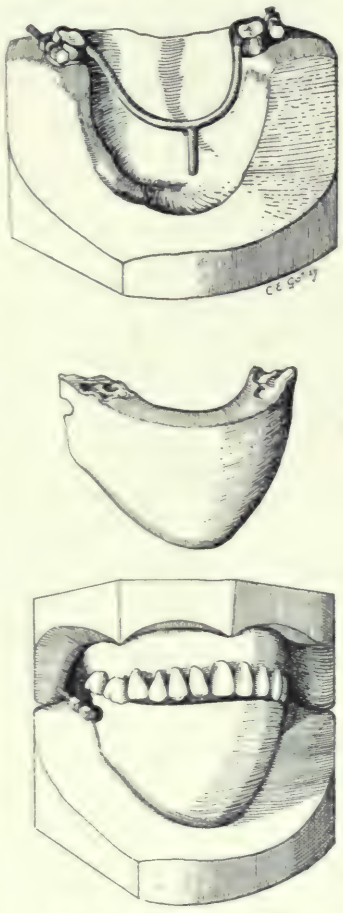


FIG. 56.—Bands and T-splint.

2. **Restoration of Mandibular Function.**—Two distinct procedures are required in order to restore to the patient some power of mastication. In the first place we must ensure at an early stage that the portions of the lower jaw which have survived shall remain in a position which will enable them to perform useful work: for upon these remnants, and resting upon them alone for support during mastication, will lie the artificial jaw. They may include a portion of the body of the mandible, or they may consist only of the two ascending rami, which, when displaced somewhat inward, forward, and upward, may yet be capable of supporting a prosthetic appliance which rests upon what is anatomically their anterior surfaces; and the degree of their usefulness will be proportional to the amount of pressure they can support. Unless these bony platforms are carefully conserved, irremediable displacements will ensue, and the mandibular function will be lost permanently and entirely. The second process to be described consists in the provision of an artificial substitute for the missing portion of the jaw. We shall consider these two subjects in detail.



FIG. 57.—Temporary splint for edentulous cases.

Prevention of Bony Deformity.—The attitude which the surviving fragments of the mandible will assume, if the case be neglected, will vary according to the position of the fractures. If the jaw has been broken at the angle, the proximal fragment will be drawn upward and outward, and, assuming that it is not restrained, will become lost ultimately in the tissues of the cheek. When, however, the fracture is further forward—in the bicuspid region, for example—the chief displacement will be inward, toward the mid-line of the mouth, with displacement upward in addition.

As soon as the local conditions are sufficiently favourable, temporary splints are adjusted which will hold the remaining portions of the mandible in a proper position—that is to say, directly under the alveolar ridges of the upper jaw, and separated from them by a sufficient intermaxillary space. This position is slightly inwards from the normal position of the intact mandible, the alveolar ridges of which are more widely separated than those of the upper jaw; and the reasons for displacing the fragments inward when the body of the mandible is lost, is that they will then act with the best mechanical advantage, and give greater stability and efficiency to the artificial jaw; moreover, a smaller prosthetic appliance will suffice, while the gap in the soft tissues will be diminished and consequently easier to close.

Two types of temporary splints are made, the selection being in accordance with the nature of the case: (1) If there are teeth existing on both sides of the jaw—for example, the third molars—metal bands are fastened to them, and these bands are connected by a heavy arch (German silver 12 A.G.) which carries a T-piece in the middle; this arch holds the two parts of the jaw in proper position. A removable vulcanite splint (*Fig.* 56) is made to fit over the arch. (2) If no teeth are available for giving attachment to these splints, a metal plate (German silver 24 A.G). of suitable size is bent into shape. To the ends of the plate moulding composition is added, and the impression of the alveolar ridges is taken with properly occluded surfaces. The plate is removed from the mouth, and after trimming off the surplus composition the model is reproduced in vulcanite rubber. This makes a simple and efficient splint, and the slight springiness at the middle facilitates adjustment (*Fig.* 57).

Practically no alterations are made until the wound is ready for plastic operation. The characteristic shape assumed at this stage by the soft tissues is seen in *Fig.* 69, p. 81.

During this stage it is important to ensure that there shall remain a buccal furrow between the cheek and the remaining portions of the alveolus of the lower jaw. For if this groove has been obliterated it is difficult to secure proper function and stability of the prosthetic appliance. To avoid this drawback, suitable flange-like extensions are incorporated with the temporary splint which prevent the disappearance of the furrow during the process of scarring. It may happen, however, that the alveolus has been in large part destroyed, or that for some other reason the buccal groove has disappeared before the temporary splint is applied. In such a case the mucous membrane is incised along its attachment to the alveolar ridge, and a cut is made deeply into the underlying soft tissues along the margin of the jaw; mattress sutures are inserted into the cut margin of the mucous membrane, and then passed through the bottom of the groove, emerging on the skin surface, where they are tied over buttons. In this manner a satisfactory buccal furrow may be re-established and maintained by the temporary splints.

3. **Restoration of the Lower Lip.**—Before proceeding to close the wound, an artificial jaw is made of vulcanite, and the patient wears this for a while in order to get accustomed to it before the plastic operation is carried out on the soft parts. The appliance has the following features: (1) It is held in place by the remaining teeth, if any are available—or, in the absence of teeth, by the alveolar ridges of the lower jaw—and by the occlusion of the upper teeth. (2) It has sufficient bulk to replace the missing bony tissue, especial attention being given to the prominence of the symphysis. (3) It is made in three sections, to facilitate removal, cleaning, and readjustment in the mouth. After the plastic operations have been completed and the soft tissues have assumed their final form, a new appliance is made as a permanent denture.

With regard to the plastic operations on the soft parts, we aim at enabling the patient to retain his saliva, to hold food in his mouth during mastication, to drink from a cup, to articulate so as to be understood, and to have a passably good appearance. To achieve these objects we must close the wound, provide it with a complete epithelial lining on its buccal surface, and restore a red lip margin.

In closing the wound we are at once faced with a difficulty, for skin-covered tissue is not available in great quantity, and yet we have to provide tissue not only to close the gap, but to cover the artificial appliance and restore the profile of the chin. The flaps used are taken from the cheeks and the sides of the neck, as shown in the illustrations. These flaps are found occasionally to have but little extensibility, owing to the presence in them of strands of scar tissue. However, they can be brought together over the artificial chin as a rule. If, after they have been sutured, there is so much tension that they remain white and bloodless, the tension may be sufficiently relieved by making small, shallow, criss-cross incisions into them with a scalpel.

The provision of a complete epithelial lining for the buccal surface may be a matter of difficulty, for although the mucous membrane of the cheek and lips is very extensible, yet there is very little of it which is available in these cases. What there is will be sufficient perhaps only to line the upper part of the lip. To provide a lining for the deep pouch in which the artificial chin has to lie, we turn up a flap of skin from the front of the neck. The fact that this is derived from a hair-bearing area does not appear to matter. For a time hairs continue to grow in the mouth, but this does not trouble the patient, and it seems that after a while spontaneous epilation takes place. Possibly the glandular structures of the skin atrophy also. At any rate, the lining, after a while appears to the naked eye almost like normal buccal mucous membrane.

With regard to the pink lip margin, the difficulty of restoring this is not so great as might have been expected. Usually some portion of the lower lip has survived, and this can often be used; for the lips can be stretched to a remarkable extent, and half a lip, detached except at one end, can be made available for the whole width of the mouth.

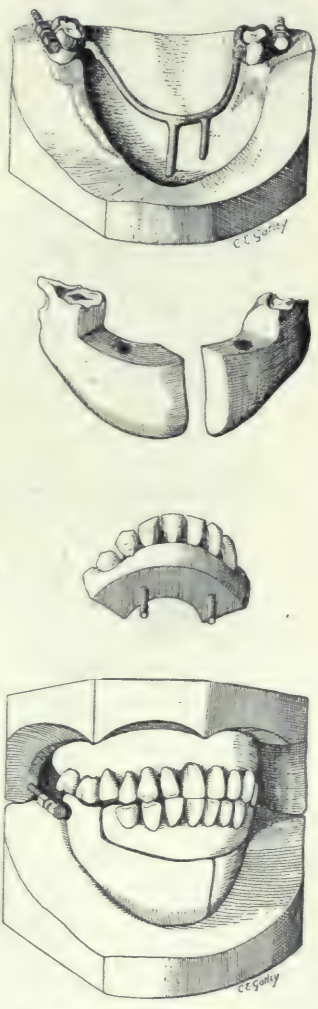


FIG. 58.—*Case* 1. Operation splints.

DETAILS OF CASES.

Case 1.—Pte. A. G. E. Wounded Aug. 4, 1916. Admitted Aug. 7. The wound is extensive, the lower lip is lacerated, the soft tissues of chin and sublingual region have been carried away, and the entire body of the mandible anterior to third molars on each side is missing. Upper jaw edentulous. Wound inflamed. Tongue swollen. Tracheotomy has been performed at C.C.S. (*Fig.* 59.)

Aug. 28.—A minor operation was performed, and a few pieces of loose bone removed. A little later patient fitted with temporary splint. As soon as wound was sufficiently clean, the following appliance was made preparatory to plastic on the soft parts. Bands were fastened on the third molars, and to these bands was fixed an arch which carried two perpendicular wires. To this arch a removable vulcanite plate, made

in three pieces, was adjusted (*Fig.* 58). The plate had sufficient bulk to fill gap in mandible and to provide a foundation with a mental prominence to support the soft tissues which were to reconstitute the lower lip and chin (*Fig.* 60).

Jan. 1, 1917.—Plastic operation performed under general anæsthetic. Anæsthetic given through a nasal tube, mouth being packed with gauze. The mucous membrane was divided along floor of buccal groove on each side as far back as the third molar, and from the hind end of each of these incisions a vertical incision was carried up on buccal surface of cheek. Superficial flaps were then made as shown in *Fig.* 61. The lower angles of these flaps consisted of skin and subcutaneous tissue only, but when the level of the buccal groove was reached, incision was carried through into the mouth and continued backward along buccal groove as far as anterior border of the masseter; behind this the flaps once more consisted only of skin and subcutaneous tissue. As soon as these flaps had been freed and bleeding arrested, temporary appliance already described was inserted, the two halves of lip were sutured, and mucous membrane was united with



FIG. 59.—*Case* 1. First photograph.



Fig. 60.—*Case* 1. Appliance fitted preparatory to plastic operation.

catgut sutures from above downward. The cheek flaps were now rotated forward and united along the mid-line. When this had been done there remained a large raw surface, triangular in shape, on each cheek. These were diminished in size, though not completely closed, by a few sutures.

At the end of this operation there was an area uncovered with epithelium on inner surface of chin, as the mucous membrane was not available in sufficient quantity to cover the mental prominence of the artificial jaw. As a result a chronic ulcer remained, and by its contraction caused depression of the lower lip. The condition resulting after this operation is shown in *Fig.* 62.

May 15.—Second operation under local anæsthetic. The ulcer in mouth was excised together with the overlying scar. Mucous lining of mouth completed by flaps of mucous membrane. Flaps of skin and subcutaneous tissue were then made as shown in *Fig.* 62, and sutured together in the mid-line. This raised the lower lip and placed it in contact with the upper.

May 21.—A support was applied in order to prevent the retraction of the lip during healing of the wound.

July 14.—The patient supplied with permanent plates of the following kind: (1) An ordinary upper plate with an inclined plane surface at the region of tuberosities; (2) A

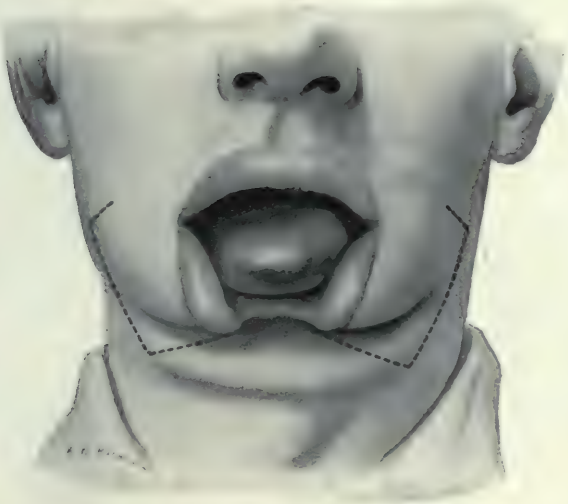


FIG. 61.—*Case* 1. Diagram of first plastic operation.



FIG. 63.—*Case* 1. Permanent dentures.



FIG. 62.—*Case* 1. Diagram of second plastic operation.



FIG. 64.—*Case* 1. Photograph of final cast.

lower plate made with hinge in the middle (*Fig.* 63) which allowed the two halves to fold together to facilitate introduction into the mouth ; this hinge can be locked, when the appliance is in position, by means of a bar along lingual aspect of plate ; this denture also has inclined planes at back, which correspond with and meet those of upper plate ; the purpose of these is to force lower plate into position and to keep it there during mastication ; on the anterior surface of the apparatus is a deep furrow with ridge below corresponding to mental prominence ; this has caused a corresponding groove in the soft tissues, and also served to support the lower lip.



FIG. 65.—*Case* 1. Final photograph.

Patient's final condition is shown in *Figs.* 64, 65. He has a good profile and a fair front view. He can drink normally, hold his saliva, speak plainly, and masticate soft food—for example, chicken, potatoes, and bread—and does not appear to find the artificial jaw troublesome.

Case 2.—F. N. Wounded Aug. 21, 1916. Admitted Aug. 23. A large shell wound of chin with extensive loss of soft tissues. Lower lip lacerated. Body of mandible missing from right bicuspid region to left third molar. Only one molar (right) remaining in lower jaw (*Figs.* 66, 67, 68). Various minor operations were performed under novocain, for removal of sequestra, extraction of roots from upper jaw, and partial suturing of borders of wound. Temporary retention splints applied.

Feb. 2, 1917.—An appliance made for patient to wear preparatory to plastic operation on the soft tissues, composed of hinged plate of suitable size and bulk which rested upon



FIG. 66.—*Case* 2. First photograph.



FIG. 67.—*Case* 2. First photograph.

remaining portions of alveolar ridges of lower jaw, the occluding surfaces in molar regions receiving the cusps of upper teeth which helped to retain plate in position, while a second plate interlocked and held apparatus together.

Feb. 13.—Plastic closure of wound under novocain. Cheek flaps formed as in previous case (*Fig.* 71), and the lip edges and mucous membrane joined until the

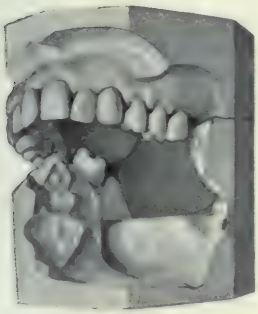


FIG. 68.—*Case* 2. Cast (inside) taken shortly after injury.



FIG. 69.—*Case* 2. Second photograph.



FIG. 70.—*Case* 2. Photograph of final cast.

tension forbade further suturing. This left a gap through which artificial chin (not shown in the illustration) projected. Gap was closed by turning up a triangular flap

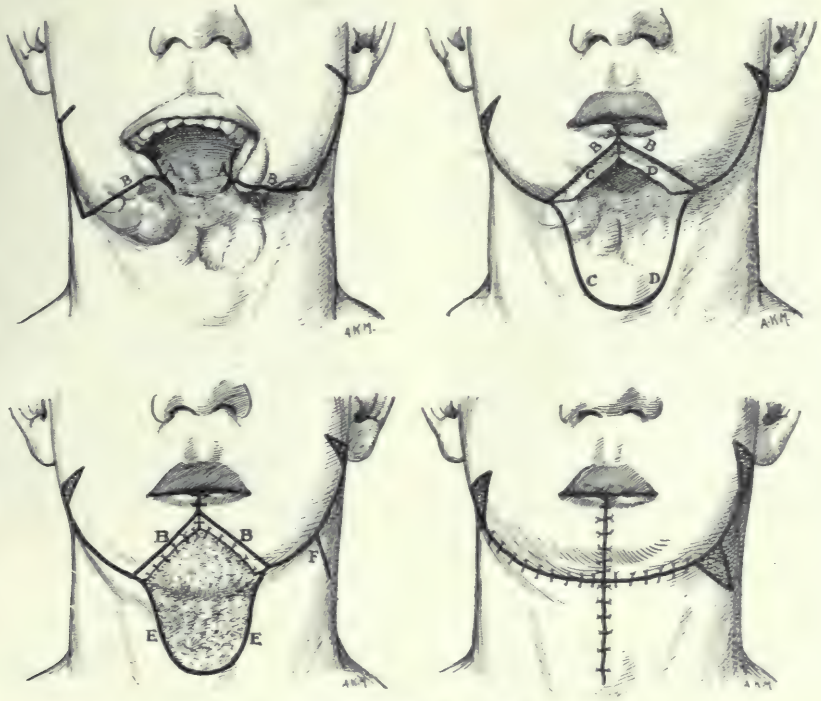


FIG. 71.—*Case* 2. Diagrams of plastic operations.

of skin from the neck and suturing this to edges of mucous membrane, epithelial surface facing inward so that it lay in contact with vulcanite appliance. The cheek flaps were now brought together over this and united along the median line, and the raw surface on anterior surface of neck was closed by drawing together the skin of neck, which is plentiful in this region. Tension of cheek flaps when they were stretched over the artificial mental prominence rendered them white and bloodless. This tension was sufficiently relieved by criss-cross incisions.



FIG. 72.—*Case* 2. Final photograph.

After wound had firmly healed, the patient was supplied with a permanent appliance similar to that used in the former case. The final condition of patient is shown in the photograph (*Figs.* 70, 72) The result was satisfactory both as regards function and appearance.

Case 3.—F. S. Wounded July 6, 1916. Admitted July 8. Extensive shell wound of chin. Great loss of soft tissue, including greater part of lower lip and chin. Mandible missing from angle on right side to second molar on left. The second and third molars present. Tongue much swollen. A small portion of shell was removed from right side of neck, 1½ in. below the ear, under novocain. (*Figs.* 73, 74.)

Temporary splints adjusted at an early stage and retained until shortly before closure of wound. Preparatory to the main plastic operation an appliance was made resembling that made for *Case* 2, but a removable condyle guide was adjusted on right side,



FIG. 73.—*Case* 3. First photograph.



FIG. 74.—*Case* 3. First photograph.

as there was no bony tissue on that side to give support to artificial jaw. This guide consisted of a movable bar attached to third upper molar and passing down along lingual aspect of lower plate, while in front of bar was a hooked wire attached to the plate ; during mastication this wire glided over the bar and prevented the plate from being pushed backward.

July 28, 1917.—Plastic operation under novocain. The details of this operation and flaps used were similar to those in *Case* 2, and no separate description is necessary (see *Fig.* 71). The permanent prosthetic appliance was similar, too, to that used for *Cases* 1 and 2, except for the addition of the condyle guide. The final condition of patient is shown in *Figs.* 76, 77.



FIG. 75.—*Case* 3. Second photograph.

Case 4.—A. P. Wounded Dec. 23, 1916. Admitted Dec. 26. Extensive shell wound causing laceration of soft tissues and fracture of mandible. From right cuspid to left angle the lower jaw is entirely missing (*Fig.* 78).

April 1, 1917.—Patient having been fitted with artificial jaw of vulcanite, a plastic operation was performed under novocain. Cheek flaps were made, and a symmetrical triangular flap was turned up from neck to complete floor of mouth. A great difficulty was experienced because the left cheek flap consisted mainly of bulky scar tissue which was inextensible and was rotated into position with difficulty, and when sutured into place much puckering of the face resulted, while there remained a large triangular raw surface on the left cheek which it was not possible to cover.

May 16.—Second plastic operation to cover raw surface on left cheek.

Aug. 15.—Patient has large scar on left side of face, left corner of mouth is protuberant owing to thick scar tissue underlying the skin. Salivary fistula



Fig. 76.—*Case* 3. Final photograph.



FIG. 77.—*Case* 3. Final photograph.

remains in left side of neck. Patient cannot open the mouth well. Is having massage of the face.

Nov. 9.—Trismus has disappeared and scar tissue become much more supple. Operation: salivary fistula closed; left corner of mouth improved by removal of triangular piece of skin together with mass of underlying scar tissue.

Jan. 18, 1918.—Fourth plastic operation in order to remedy depression of the lower

lip. Permanent prosthetic appliances made consisting of upper and lower vulcanite plates. Lower plate retained by two clasps round right bicuspids and horizontal spring attachment on left which acts as a condyle guide (*Fig.* 80).

The final result is shown in *Fig.* 79.



FIG. 78.—*Case* 4. First photograph.



FIG. 79.—*Case* 4. Final photograph.





FIG. 80.—*Case* 4. Permanent dentures. Horizontal spring and lever. To the upper denture is attached a bar about one inch in length, designed to carry a button at each end. (Where there is sufficient vulcanite the buttons are attached directly to the denture.) A lever is constructed with the posterior button as a fulcrum. Its long arm travels in a groove on the buccal aspect of the lower denture, while a spiral spring acts between the end of the short arm and the anterior button. A small extension at the end of the long arm has contact with a pin which originates in the lower denture. By its action the device as a whole serves to keep the dentures in position, and also prevents the lower denture and remaining portion of the mandible from rotating to the left. It does not interfere with either incisal or lateral movements in mastication.

CONCLUSIONS.

Fortunately such extensive destruction of tissues as occurred in these cases is not often seen. In the main we have followed the same line of treatment in all. The principal points to be observed are :—

1. The preservation of the surviving portions of the mandible in the desired position.
2. The substitution of lost bony tissue by vulcanite appliances before the performance of plastic operations on the soft parts.
3. Postponement of the main plastic operation until suppuration has ceased and the patient is in a good physical condition.
4. The use of a similar scheme of flaps in all the cases.

As seen in the photographs, a reasonable fullness of the chin was provided, and the general result, though far from perfect, is not repellant to the eye. The speech of the patients is fair and intelligible, and undoubtedly will continue to improve. The artificial plates are simple and removable, and have good stability without the aid of additional springs—though to this the fourth case is an exception, for here it was necessary to employ a spring to control the left side.

As to the efficiency of the jaw to masticate food, we may state that a good part of this function has been restored. Normally the human jaw can exert about two hundred and fifty pounds of pressure, while the force required for mastication of ordinary food reaches to fifty-five pounds. When part of the mandible has been lost, the potency of the remainder will be proportional to the amount of bone remaining that can support artificial dentures. This being so, it might be thought that mastication would be done only by the posterior parts of the plates where they rest upon firm surfaces, and that the anterior part of the artificial jaw, resting as it does on soft tissues alone, would be unable to participate in the function. To some extent this is true. Yet it is possible, by means of inclined planes upon the posterior ends of the plates, to project some portion of the biting force to the artificial incisors. A simple plan may be used to enable the patient to chew with greater force and satisfaction, namely, by teaching him to press up the chin with the left thumb during each act of mastication. With practice and perseverence the habit becomes acquired, and, while being helpful, it is not unsightly.

An ideal restoration of a lost mandible would involve re-establishment of bony continuity by grafting. We hope that means will be found to achieve more perfect results by such a method. This is a problem that awaits solution in the future. At the present time it is satisfactory to know that an artificial jaw can be both a useful and a practical substitute for one that has been lost.

NOTES ON THE PRINCIPLES AND RESULTS OF TREATMENT IN 200 CASES OF INJURIES TO THE FACE AND JAWS.

By Captain W. MAXWELL MUNBY, R.A.M.C. (T.F.),
Captains A. ALAN FORTY and A. D. SHEFFORD, *Dental Officers.*

Department for Treatment of Injuries to the Face and Jaws, 2nd Northern General Hospital, Leeds.

It has been truly said that "the excellence of every art depends upon the complete accomplishment of its purpose," and it is the intention of this communication to classify and systematize the results obtained in two hundred cases of face and jaw injuries treated in a special department of a general hospital. These cases belong to a series, and have not been specially selected, so that our results may not be suspected of partiality.

Much has been written hitherto by British, colonial, and foreign authors describing principles of treatment, specifying types of splints and apparatus employed, outlining the procedure in dealing with cases seen early and late, devising nomenclature, etc.—all essential in an exhaustive treatise on jaw surgery and jaw orthopædies. Little, however, has been published giving results of treatment, tabulating the duration of stay in hospital, destination of the patient, whether returned to duty, etc. The present contribution essays to meet this need, and we trust it may stimulate the publication of others from the various special centres where the treatment of jaw and face injuries is undertaken.

In our series of 200 cases, 145 were admitted with definite injury to bone; the remaining 55 were suffering from injuries to the soft parts only, giving rise to various disabilities.

INJURIES TO BONE.

Table 1.—Showing the Number and Percentage of Mandibular and Maxillary Fractures (exclusive of Alveolar Fractures), and of Alveolar Fractures.

Part Fractured	Number	Percentage
Mandibular fractures:—		
(*a*) United on admission	15	10·4
(*b*) Incomplete	9	6·2
(*c*) Complete	95	65·5
	—119	
Maxillary fractures	8	5·5
Alveolar fractures	18	12·4
Total	145	100·0

Fractures of the Mandible.—

a. United on Admission.—This class consists of 15 cases, all of which required prosthetic treatment, many of them surgical or other treatment in addition—such as attention to sinuses, and extractions—similar to that frequently necessary in complete fractures.

b. Incomplete Fractures.—There were 9 of these cases, in 8 of which there was a crack either at the angle or in the body of the jaw, while in the ninth a small fragment was detached from the anterior border of the ascending ramus.

c. Complete Fractures.—This class consists of 95 cases, which are classified in *Table* 2 according to the region in which they occur.

Table 2.—Classified List of Complete Mandibular Fractures.

Site of Fracture	Number	Percentage
Mesial or incisor region	26	27·4
Canine, premolar, or molar region	32	33·7
Angle	21	22·1
Ascending ramus, including condyle and coronoid	10	10·5
Multiple	6	6·3
Total	95	100·0

It is often difficult to locate fractures definitely to any one region, so that the above classification has been adopted merely for convenience, and is more or less arbitrary.

The amount of comminution present depends upon the nature and velocity of the projectile, the angle at which the blow is received, and the distance which the missile has travelled before impact. In the majority of gunshot wounds there is considerable comminution, while in 'civil' fractures (due to kicks, blows, or falls)—of which there are 14 in this series—there is, on the other hand, little or no comminution.

Fractures of the Maxilla.—Excluding alveolar fractures, there are only 8 cases in this class. Of these, 7 were injuries to the hard palate, varying in extent, opening into the nasal cavities or maxillary sinuses. The eighth was a horizontal fracture above the palatine vault.

Fractures of the Alveolus.—This class consists of 18 cases. They were met with in one or both jaws, and varied considerably in extent. They are associated with fracture of the teeth.

FALSE TRISMUS OR LIMITATION OF MOUTH OPENING.

This clinical condition has been met with in 66 out of the whole series of 200 cases: in 25 of these it was definitely associated with fracture of the mandible: in the remaining 41, fracture either had been definitely excluded by *x*-ray examination or was very doubtful.

In all cases of definite fracture the site of the injury has been either in the ascending ramus or angle, and in such it is obvious that the muscles of mastication have been involved. Where fracture is absent or doubtful, the injury has been of such nature as to involve some fibres of the masseter, temporal, or pterygoid muscles.

The condition in many of the cases is largely due to slight spasm of the muscular tissue resulting from injury, and is easily and rapidly overcome without recurrence. In other cases it results from the presence of scar tissue limiting movement. These are more obstinate, especially where the temporal muscle is affected, and recurrence is more probable. In a third class—the most obstinate of all—the condition is due to functional spasm of all the muscles attached to the mandible.

UNCOMPLICATED INJURIES TO SOFT PARTS.

There were 14 cases suffering from slight disability due to the presence of a foreign body or pain in the scar during mastication. They require no further comment.

PRINCIPLES OF TREATMENT.

A brief résumé of the treatment—as far as it could be ascertained—which had been carried out previous to admission to this hospital may be of interest. In the majority

of cases the only earlier treatment had been directed to the soft parts, and the bony injury had been neglected. In a few cases wounds had been sutured and foreign bodies removed. The following arteries had been ligatured for secondary hæmorrhage : external carotid once ; facial twice ; lingual and temporal once each. Tracheotomy and laryngotomy had each been done once. Splints had been applied to one or both jaws in 19 cases. In the majority of these the mouth was in a very septic condition and the splints had to be removed almost immediately. Obviously many teeth had been retained which were not only useless but detrimental to recovery.

Early routine treatment is directed to the control and elimination of sepsis, the care of external wounds, and maintenance of the patient's health. Patients are instructed in oral hygiene, whilst constant lavage is carried out by the nursing staff. The patient's diet is arranged according to his ability to deal with certain types of foods, and follows fairly closely, with certain modifications, the scheme advanced by Captain Holt, at one time medical officer in charge of Croydon Jaw Hospital.

The study of radiographs always precedes any decision upon the necessary subsequent treatment ; these radiographs are taken from as many aspects as are considered advisable. As a result a definite line of treatment is suggested, and the preliminary stage consists in the removal of teeth, or roots of teeth, involved in the area of fracture, except in those cases where retention is temporarily considered advisable from the point of view of controlling fragments otherwise devoid of efficient anchorage. In some cases a cast cap-splint is loosely adjusted within twenty-four hours of the removal of such teeth, so that displacement may be effectually controlled, and such a splint is not cemented in place until any sepsis which may be present is well under control.

In the vast majority of gunshot wounds of the face and jaws, comminution of bone and loss of tissue results, together with certain types of resultant displacement of the fragments, and often facial asymmetry. The re-establishment of a normal occlusion and orientation of the dental arch is never sought at the expense of bony union. In those cases in which comminution and tissue loss are absent (in some gunshot fractures, but especially in fractures of a 'civil' nature, the restoration of the normal occlusion is perfectly compatible with bony union ; while in cases where tissue loss is very extensive (often above 4 cm.), any idea of ultimate bony union is generally impracticable, and the normal occlusion is restored so far as it is possible to do so, the future of the case depending upon the efficacy of ' bone-grafting operations.'

The essential importance of retaining (especially in the more extensive fractures) all pieces of bone which have adhered to the periosteum must be insisted upon, as such vital foci are eminently necessary in the process of ossification, acting as grafts in the process of repair, whilst their removal lessens the incidence of osseous and tends to promote fibrous union. More than one case which has resulted in fibrous union can be definitely traced to the removal of such bone fragments. This, of course, cannot be said to apply to alveolar bone, which exerts no influence on the reparative process. Neither granulation tissue, nor the subsequent callus, is laid down beyond a limited distance from the mother tissue, and reparative callus cannot bridge across definite gaps, so that the presence of such foci of ossification is very essential.

Bony union once obtained, the correction of any abnormal occlusion is proceeded with. In many cases, all that is necessary is the adaptation of a prosthetic appliance owing to the man's poor natural denture ; whilst in others various orthodontic appliances are used. This stage is carried out when, although the mobility of fragments is arrested by callus formation, yet such callus is still capable of extension and manipulation under mechanical force. Obviously this stage should not be delayed until after the ossification of the callus.

For immobilization of fragments, the cast cap-and-bar splint is universally used, either singly, or in some cases in the intermaxillary form (especially where only a few teeth are available). These splints are easily cleaned, comfortable, and eminently successful.

Fibrous union is treated by a suitable prosthetic appliance. Bone-grafting is being tried in some cases, and we hope to make a communication on the subject later.

Sinuses which persist after two or three curettings combined with the use of 20 per cent lactic-acid packing or chloramine paste, are treated by cutting down upon the bone, exposing it freely, and removing sequestra which maintain the infection.

Limitation of opening the mouth yields more or less readily to intermittent screw-gag pressure (a modified Holt pattern, or lever arm gag), accompanied by massage, which is also given as a routine procedure in the majority of cases of mandibular fracture.

In this series there were 11 cases requiring plastic operations. Three of these only required readjustment of the red margin of the lip, the scar being first excised ; and two required the closing of a fistulous communication with the mouth ; these call for no comment. Four required more extensive operations on the lower lip. In these and in all such cases where the normal contour of the dental arch is destroyed by loss of teeth, etc., this is restored by a vulcanite appliance which is fitted before plastic procedure is undertaken ; this acts as a framework on which to remodel the soft parts. Only one of these cases calls for comment. The patient had had the middle fourth of the lower lip blown away to the depth of one inch. Incisions were made on each side parallel to the lip at the level of the lower margin of the gap, and extending over the mandible to the neck, and the soft parts were freed from the deeper structures sufficiently to allow the two margins of the lip to be sutured and so obliterate the gap. The mouth was thus made slightly smaller, but not unduly so. Of the remaining two cases, one was a scar excision calling for no further notice. The other was a pensioner who, in addition to fracture of the lower jaw, had received considerable injuries to the left cheek and malar bone, with destruction of the facial nerve and left eye. There was drooping of the cheek and left angle of the mouth, causing considerable deformity. An injection of wax was made just above and external to the left angle of the mouth, and a strip of fascia lata half an inch wide was removed from the thigh a few weeks later, after making incisions over the zygoma and above and below the wax depot. The fascia was passed from the zygomatic wound through the cheek substance, first deep to the wax depot, then superficial to it back to the zygomatic wound, where both ends were sutured to the fascia over the zygoma, the angle of the mouth being over-elevated. This operation, combined with scar excision, considerably improved the appearance of the patient.

RESULTS.

Table 3.—Showing the Final Disposal of the Men in this Series of 200 Cases.

Disposal	Number	Percentage
Returned to duty	175	87·5
Discharged from the army	13	6·5
Transferred to other hospitals ..	7	3·5
Pensioners admitted as such ..	4	2·0
Death	1	0·5
Totals ..	200	100·0

The average stay in hospital was 104 days.

This analysis of 200 cases is an attempt to record the ultimate results obtained in some of the earlier cases seen by us in 1916–1917, and it is our hope to publish some further statistics and results of the large number of face and jaw injuries—well over 1000 to date—which have been treated in this special centre.

It is perhaps a truism to mention the invaluable aid in diagnosis and treatment rendered by accurate radiographs taken—as soon as a case is admitted, and serially—to demonstrate the changing conditions as a case progresses, and we have received great assistance in this work from Captain Stansfield, the radiographer to the hospital.

Table 4.—The Results of Treatment in Fractures of the Mandible, with the Sites in which Non-union occurred.

Result	Number	Percentage
Bony union	80	83·9
Non-union, angle	1	1·1
,, lateral	5	5·3
,, mesial	2	2·2
,, multiple	2	2·2
,, ascending ramus ..	5	5·3
Totals ..	95	100·0

In all except three of these cases of non-union the shortest period elapsing between injury and admission to hospital was two and a half months, and the average period was a little over ten months.

The following selection from the above series illustrates some of the typical cases and their subsequent treatment.

Case 1.—Wounded by shrapnel, April 9, 1917. Admitted April 23. Radiography shows a comminuted fracture of the symphysis region, and a triangular fragment detached from lower border of mandible in this region. Alveolar process carrying 5.4.3. practically detached; and these teeth, together with several septic roots of mandibular molars, were removed. On June 4 an intermaxillary cap-and-bar splint (metal Gunning) was adjusted. Sept. 1, splint was removed and union had resulted. Lack of occluding power owing to deficiency of mandibular teeth made good by an artificial denture.

Case 2.—Bullet wound, Nov. 13, 1916. Admitted Jan. 3, 1917. Previously, a cap splint had been cemented in place. Oral condition extremely septic. No union had occurred. Wound of entry still persisted on right side of chin. Point of exit was on left side of chin, and a comminuted fracture in the right canine and premolar region resulted. There was some displacement, the lesser fragment had been drawn inwards, to be overlapped by the larger (left) fragment, which had been drawn round to injured side. Second premolar of left side was seen to be directly in the area of fracture, and was removed. Although tissue lost is considerable, several bony foci remain—which are of essential value in ultimately gaining bony union. Sinus persisted at wound of entry, but eventually healed. Submental abscess also developed; this delayed complete immobilization (a cap splint being worn loosely for a time, so that the displacement was overcome), which was eventually practicable on Feb. 2. May 7, splint removed and jaw quite firm, with bony union. Patient discharged to duty June 15.

Case 3.—Fracture at the right angle of the mandible without comminution or loss of tissue. Patient wounded, Oct. 17, 1916, and an intermaxillary splint was adjusted in France. Bullet entered left cheek, whilst the point of exit was immediately below lobule of right ear. On admission, Jan. 6, 1917, oral condition was bad and pronounced sepsis very apparent. Splint was removed and no union had resulted. Radiography shows the right mandibular third molar directly involved in line of fracture; it was consequently removed, together with several septic roots in the maxilla. A sinus existed beneath right ear and persisted for some time. The oral condition at length being satisfactory, an intermaxillary splint was adjusted, and on June 15 the patient was discharged to duty. Limitation of opening had resulted, owing to involvement of masseter and internal pterygoid muscles as well as prolonged closure during the period of immobilization, but was rapidly overcome by intermittent gagging and massage.

Case 4.—Complete fracture of condyle across its base. Wound received Oct. 12, 1916, and man admitted, Nov. 14. Entry wound existed on left cheek, immediately above middle of zygomatic arch. The mandibular and maxillary teeth were wired together in France. On admission, the clinical condition was that of limitation in opening mouth, with salivary fistula in left cheek, which was treated by introduction of a silver tube. No clinical evidence of mandibular fracture, and after the condition of 'false trismus' had been overcome by massage and gagging, the patient was discharged to duty, May 18, 1917.

Case 5.—Double fracture of right body of the mandible. Patient wounded by high-explosive shell, April 25, 1917, there being a large entry wound on right side of neck. An intermaxillary splint (metal Gunning) had been cemented in place, an excess of cement being present; a large piece of composition covered part of it, evidently to protect the tongue from injury. On

admission, May 18, mouth was found in a very septic condition; radiography shows an oblique fracture posterior to last molar tooth, in which a portion of tooth-root and mandibular molar tooth are involved, and a second fracture in right canine region, involving that tooth. A freely-discharging sinus was present at the entry wound. The splint was removed, and the above-mentioned teeth. June 5, the sepsis had subsided and sinus healed, so that an intermaxillary cap-and-bar splint was cemented in place. This was eventually removed to allow the extraction of second and third right maxillary molars, which were seen to preclude the forward movement of posterior fragment. A splint was again adjusted, and removed on Aug. 3, when it was found that fibrous union (pseudo-arthrosis) had resulted. A prosthetic appliance was provided which rendered mastication quite efficient, and the man was ultimately discharged to duty (C 3). This case shows the evil effects of delay in removing involved teeth, of the presence of uncontrolled sepsis, and finally of neglect to allow the forward transition of the posterior fragment, all of which combined to produce non-union.

Case 6.—Wounded, Sept. 25, 1916; admitted, Nov. 3. Injury due to a bullet which, entering left angle of mouth, issued about 1 in. above the right angle. Radiography shows comminuted fracture of right angle of mandible, and a second fracture extending obliquely through the right body in the first mandibular molar region. Roots of two mandibular molars and the second premolar appear to be impacted in the fracture. A Hammond splint had been adjusted, and was removed, together with the molar and premolar roots and several maxillary teeth. Mouth in very septic condition. Nov. 15, an intermaxillary cap-splint was cemented in place, and when removed on Dec. 15, jaw was firm, and bony union obtained. This man was discharged to duty subsequently.

Case 7.—Incomplete fracture of left body of mandible, only the lower border of jaw being involved; there was no clinical evidence of fracture. Wounded, July 30, 1917; admitted Aug. 13. Patient was discharged to duty on Sept. 10: the only treatment necessary was the removal of 7.5.4., which were quite loose.

In conclusion, we should like to thank Lieutenant-Colonel H. Littlewood, C.M.G., administrator of the hospital, and consulting surgeon to this department, whose valuable advice and courtesy have been of real assistance in our work.

PRIMARY AND DELAYED PRIMARY SUTURE OF GUNSHOT WOUNDS.

A REPORT OF RESEARCH WORK AT A C.C.S., DEC., 27, 1917—MARCH 1, 1918.

Director of Research Work: CAPTAIN FORBES FRASER.

Operating Surgeons: CAPTAINS J. W. DEW, D. C. TAYLOR, A. W. DENNIS, M. W. B. OLIVER, and HENRY STOKES. *Radiologist:* CAPTAIN N. S. FINZI. *Anæsthetists:* CAPTAINS G. MARSHALL, C. F. HACKER, A. S. BLACKWELL, and LIEUTENANT G. R. PHILLIPS. *Physician:* CAPTAIN J. A. RYLE.

WITH WHICH IS INCLUDED A

REPORT ON THE BACTERIOLOGY OF WOUNDS.

BY CAPTAIN ADRIAN STOKES AND MAJOR W. H. TYTLER.

I. GENERAL OBSERVATIONS.

FOR the purposes of this work during the period mentioned, only men suffering from wounds of the upper and lower limbs have been admitted to the C.C.S. Of these, 60·8 per cent have been entered on the research list as being cases suitable for immediate or early suture.

Patients suffering severely from shock and loss of blood, who are not in a condition to bear a thorough cleansing operation, and whose tissues may have lost much of their normal power of resisting infection, are not as a rule suitable subjects for primary suture, though they may sometimes be fit for closure of their wounds after the lapse of a few days. Patients who show signs of already established infection of the tissues surrounding the wound must also be rejected; these form a large class, and include the majority of men whose arrival at the C.C.S. has been delayed beyond twenty-four hours. Multiple wounds are seldom suitable, not only on account of the lengthy operation involved, but because of the likelihood of one failure causing infection of other wounds. Trivial wounds, and clean through-and-through bullet wounds without damage to main vessels or nerves, are also best left alone. Patients considered unsuitable for the research list are treated by us in the usual way, and evacuated to the base when they have sufficiently recovered.

Patients whose wounds have been sutured are kept here till their wounds have healed, or until the treatment has definitely failed. We have, as far as possible, limited our investigations to primary suture at the time of operation, and to delayed primary suture, which may take place at any subsequent time before granulations have formed.

Secondary suture, by which we mean suture after granulations have formed, we have reserved chiefly for wounds with virulent infections such as those in which primary suture has failed on account of the presence of hæmolytic streptococci. We feel that secondary suture is better investigated at the base and in England, where so much important work has already been undertaken in this direction.

Reference to the figures in Part II will show that the vast majority of the wounds which we have dealt with were infected before operation. Success in primary suture must, therefore, depend on early operation, whereby the infected area may be more or less thoroughly removed before sufficient time has elapsed to allow of infection penetrating into the surrounding tissues.

As this removal can rarely be complete, other factors are :—

1. The ability of healthy tissues to deal with a limited amount of infection, provided the larger sources of bacterial growth have been removed.

2. The possible action of chemical antiseptics in destroying or inhibiting the growth of bacteria still present after operation.

With these principles in mind we have operated on a series of cases, the details of which will be found in Part II.

Antiseptics.—We have sutured wounds without the aid of antiseptics, and we have also used B.I.P.P., flavine, and, more recently, dichloramine-T dissolved in chlorinated soft paraffin (chlorcosane). Some of the wounds have been treated by washing with ether, after the method in common use by French surgeons. Soap solution, which has of late been used with success by Captain Haycraft and others, is also being tried by us. The numbers of wounded who have been admitted are too small to enable us at the present time to draw definite conclusions as to the relative value of these chemicals. At present we can go little further than to show it is possible to suture wounds with considerable success with the use of each of these substances, and also without any antiseptics at all.

Before describing in detail the methods we have used, we wish to acknowledge our indebtedness to many papers on the subject of primary suture published by French surgeons, and in particular to the article by M. le Gros (*Bulletin de la Société de Chirurgie*, October, 1917), which forms the basis of the work we have undertaken, although the mode of operation adopted by us differs from that advocated by him.

X Rays.—Every case, excepting through-and-through wounds or contour wounds with no damage to bone, is examined by *x* rays before operation. We understand that it is a common event after a foreign body has been removed at the C.C.S., for surgeons at the base to find others present which keep up sepsis. It is, therefore, unjustifiable to close a wound till it is certain that all foreign bodies have been removed.

Culture.—A specimen is taken from each wound for culture immediately before operation. For this purpose a swab is used, contained in a glass tube in the upper end of which cotton-wool is packed. The whole is placed in a test-tube, the mouth of which is also plugged with wool. The apparatus is sterilized in the autoclave, and when the specimen is to be taken, the inner glass tube with the swab is withdrawn and placed in contact



FIG. 81.—Stokes' swab and tube used in taking specimens for culture.

with the wound. The swab is then thrust down into the depths of the track and thoroughly smeared on all parts of the wound which can be reached. It is then withdrawn into the tube, and both are replaced in the test-tube. This method of taking specimens, which appears to us to be efficient, and to guard against contamination, we owe to Captain Adrian Stokes (*Fig.* 81.).

Disinfection of Skin.—The patient's skin is shaved, washed with soap and water followed by spirit, then painted freely with a 5 per cent solution of picric acid in spirit.

Operation.—We wish to lay stress on the fact that, excepting only comparatively superficial wounds which could be excised as a whole without doing serious damage to the limb, no attempt has been made by us in the course of this work to perform excisions *en bloc*. Most of the French surgeons who advocate primary suture of gunshot wounds appear to aim at aseptic excisions in which dead or soiled surfaces are not touched with the knife or scissors. Thus, they recommend that a lodging wound be treated by excision in the form of a cone which includes the foreign body and its bed at its apex ; a through-and-

through wound by the excision of two cones whose apices meet ; a compound fracture by ablation of a wedge of soft parts down to the bone. Their object is to avoid entering the track, and to render the operation as nearly an aseptic one as possible, a method similar to that used in civil practice for the removal of a malignant growth.

We feel that this ideal method, even when anatomically possible, is only applicable to exceptional cases in which it can be carried out without doing serious injury to muscles and other structures of the limb. To use it in deep lodging wounds, in through-and-through wounds, and in the general run of compound fractures, would in our opinion lead to unnecessary loss of tissue, and often to irreparable damage to the function of the limb.

Our method has been to excise a very narrow margin of skin round the wound in the form of an ellipse, to prolong the incisions sufficiently to obtain a full exposure of the track, and then, with the help of good retraction, to remove its walls with scissors or knife. As little healthy tissue as possible is removed ; but soiled, dead, or severely bruised muscles are snipped away till healthy contracting and bleeding tissue is exposed.

It will be seen that this form of piecemeal excision of wounds, being performed to a great extent from within the track, has no pretension to being an aseptic operation, and differs entirely from ideally aseptic excision *en bloc*, which aims at removing the whole track from outside without cutting into it. Success in suture after excision piecemeal must depend on the ability of healthy tissues, aided perhaps by chemical antiseptics, to deal with infection, provided the latter be not too massive or too virulent.

A proportion of failures must be expected, in the presence of virulent infection, even if the operation has been properly performed. A method such as this, whose success depends to a great extent on factors of which we are ignorant, is obviously open to criticism. Its scope, however, is so much larger than that of excision *en bloc*, and its advantages over the latter in avoiding unnecessary removal of tissue are so important, that if in practice the results obtained by it are proved to be sufficiently good, and the risks attending it to be sufficiently small, then the use of piecemeal excision appears to us to be justified. While in the presence of infection this operation can never be aseptic, yet there are degrees of soiling of raw surfaces, and every precaution should be taken to avoid unnecessarily contaminating the rest of the wound from dead and infected material. By means of free incision good access should be obtained to every part of the wound, and with the aid of retractors all excision should be carried out under view. The use of the fingers to explore tracks should be absolutely discountenanced. By changing of instruments or by frequently rinsing them in 1–20 carbolic, and by care in manipulation, gross soiling of raw surfaces can, as a rule, be avoided. The operation is not complete till every part of the wound has been dealt with, and every fragment of dead muscle removed. Important structures, such as main vessels and nerve trunks, which cannot be excised, should be carefully cleaned with knife, scissors, and swabs. If every part of the track has not been actually seen and cleansed, primary suture should not, as a rule, be undertaken.

The use of dyes, such as 5 per cent solution of methylene blue or brilliant green in 20 per cent formalin, has been advocated, particularly by French surgeons, as a means of distinguishing living from dead tissue. Experiments have been made by us in the use of these dyes, with the result that there is some individual difference of opinion as to their value. They certainly stain dead tissues deeply and intensely, while the cut surface of living muscle is only lightly stained on the surface. We are inclined to think that their use may be of some value in dealing with large wounds where small patches of dead tissue are apt to escape attention, and also should be a help to operators who have not much experience in the excision of gunshot wounds.

Compound Fractures.—In the case of compound fractures, the wound in the soft tissues is dealt with as above described, and a good view of the fracture being obtained by retraction, the cleaning of the bony lesion is proceeded with. Foreign bodies are removed, loose fragments lifted out, and sharp points cut off. Access is gained to the fractured surfaces by levering fragments apart, and every crevice is carefully cleaned by small spoons, scrapers of various shapes, and burrs. Blood-clot is carefully wiped away from cracks in the neighbourhood of the main fracture.

We are careful to remove as little bone as possible, knowing that regeneration of bone is a difficult and tedious process. Only fragments which have lost all their attachment are removed; those retaining even a small connection with periosteum are preserved.

The closure of cavities left in bone after the removal of a foreign body or loose fragments often presents considerable difficulties. Such cavities, if left to fill with blood-clot, generally become septic and lead to failure of the operation. In one such case (a femur), a muscle flap with good blood-supply was cut from the vastus externus and made to fill the cavity; unfortunately it sloughed, infection with anaerobes took place, and the wound had to be opened. Fat grafts have been used by several of us with success in the neighbourhood of the knee-joint. Up to the present time our experience has not been sufficient to enable us to express an opinion as to the best method to be adopted.

The investigations of Major Martin on the spread of infection in compound fractures (British Journal of Surgery, October, 1917) are of great importance in connection with the early treatment of these injuries. He has demonstrated that penetration of bone by infection is slow in comparison with its rate of progress in soft tissues. It seems reasonable, therefore, to presume that if the infected soft tissues have been efficiently removed and the damaged surfaces of the bone thoroughly cleansed, sepsis will not occur in the bone, and a compound fracture should be expected to heal by first intention in the same way as a flesh wound. This is borne out by our experience.

The operation is completed by careful *hæmostasis*. For smaller vessels this is best secured by leaving on pressure-forceps, such as Lane's, during the operation. Larger vessels must be ligatured with catgut, but care taken that as little tissue as possible is included in the ligature. All crushed and ligatured tissue must die, and the less dead material left to form a nidus for infection the better.

It has now to be decided whether to suture the wound at once or to leave it open. Every case must be judged on its merits, and it is impossible to lay down rules which will cover all eventualities. The size, gravity, and appearance of the wound, the time which has elapsed since its infliction, and the condition of the patient, must all be taken into account. The following may be found useful as a guide in general terms. Provided (1) that the wound is not of more than fifteen hours' duration ;* (2) that the surgeon feels that he has been able to cleanse it satisfactorily, and has removed all foreign bodies ; (3) that closure can be effected without undue tension ; and (4) that the patient need not be moved for several days at least : then primary suture is justifiable. Otherwise it is advisable to leave the wound open in the hope of suturing it at a later date. Undermining of skin flaps, and other plastic measures for closing wounds, should not, as a rule, be undertaken at the primary operation, unless a bacteriological examination has already been made and it is certain that virulent organisms are not present.

Suture.—It is important that accurate coaptation of deep, as well as superficial, surfaces be obtained. 'Dead spaces' which fill with blood-clot will probably lead to failure. We have adopted the method of passing deep coaptation sutures which draw together the muscles and emerge from the skin wide of the edges of the wound. If tension is present these are tied over rubber tubes or lead plates. The skin edges are then brought together by interrupted sutures, with an interval of ½ to ¾ inch (see *Figs.* 121, 125). We have avoided buried catgut sutures, except in wounds of joints where they have been used to close the synovial membrane. For suture material we have used silkworm gut, and silk treated with B.I.P.P. The latter has the advantage of being well tolerated by the tissues, and produces little irritation even when retained for long periods. Owing to its thickness it is not so liable as silkworm-gut to cut out. Sizes 4 to 6 China twist are used. It is prepared by boiling in carbolic (1–20) for an hour, subsequently soaking in tincture of iodine overnight, and then storing in a very liquid B.I.P.P.

* The limit of fifteen hours after infliction of the wound is about the average for wounds of moderate severity, after which we consider it wise not to attempt immediate closure. Many slighter wounds have been successfully sutured at later periods.

Drainage.—We have found that as a general rule it is better to dispense with drainage altogether. The use of rubber drainage tubes is certainly to be avoided. They appear to act as foreign bodies, and sepsis is prone to appear in their tracks, even if the tube is removed at the end of forty-eight hours. 'Viennese silk wire,' consisting of bronze aluminium wire with a fine silk core, which is recommended highly for use as a drain by French surgeons, has been tried by us. Though it acts efficiently as a drain, it appears to have the same disadvantages as rubber tubes, and to set up irritation and consequent sepsis which may lead subsequently to infection of the whole wound. If interrupted sutures are used, and not placed too close together, sufficient escape of blood and serum generally takes place between them, and further drainage is unnecessary. In the presence of persistent oozing, which in civil surgery would generally be treated by introducing a tube for a short time, it is better to pack the wound, leave it open, and suture it at the first dressing.

Progress and After-Treatment.—Our treatment has been, as stated already, to excise and suture wounds without knowing the nature of the infection at the time of operation. No other course is possible in the primary suture of gunshot wounds, as to wait for cultures to be made and examined before operating would involve certain failure in the majority of cases, owing to infection spreading during the interval into the tissues surrounding the wound. Generally, however, on the morning following operation we have had the advantage of knowing the results of both aerobic and anaerobic culture from each wound.

We have found that among the many kinds of infection which are present in the majority of the wounds with which we have dealt, one variety, viz., the *hæmolytic streptococcus*, stands out as being in a class by itself in virulence. A sutured wound infected by these organisms will almost certainly go wrong, and unless the sutures are removed at once and energetic measures taken to combat the spread of infection, not only the limb but even the life of the patient may soon be in grave danger. Other infections which we have met with in sutured wounds need not, in our experience, as a rule give rise to anxiety on the part of the surgeon, and do not often call for urgent interference. Streptococci which are not hæmolytic occasionally give rise to acute symptoms, but in our experience the majority of wounds infected by them do well. Infection by the common varieties of anaerobes alone does not appear to be of much importance, provided a careful operation has been done. The tissues will probably be able to deal with them, and if suppuration takes place it is likely to be local and easy to control. The hæmolytic streptococcus, on the other hand, *always* gives rise to anxiety on our part, and nearly always necessitates the opening of the wound. The advantage of early knowledge of the presence or absence of these organisms is, therefore, in our experience a very real one.

The statement that the hæmolytic streptococcus is by far the most virulent organism which we have hitherto met with in the wounds which we have sutured must not be taken to mean that we wish to deny that other organisms of equal virulence may sometimes infect gunshot wounds. We have some reason to believe that such organisms do occur, but we have not met with them in our present series of wounds considered suitable for early closure.

The characteristic feature of the post-operative condition of patients whose wounds have been sutured and are healing, is the general well-being of the men. They look well, are cheerful, have good appetites, and as a general rule have very little pain. There is a marked contrast between their aspect and that of patients with open suppurating wounds. Many patients have little constitutional disturbance after operation ; but a rise of temperature lasting for one, two, or three days, or even longer, is common. There may also be a raised pulse-rate, though as a rule the pulse does not remain for long above 100 except in cases of very severe wounds or of streptococcal infection. If the bacteriologist has reported that hæmolytic streptococci are absent, mere elevation of temperature and pulse in a patient who looks and feels well and complains of no pain in his wound by no means indicates impending suppuration. In all probability the fever will subside in the ocurse of a few days and healing will take place by first intention.

Sometimes local suppuration will occur, occasionally a gas-containing abscess may form ; in either case the removal of one or more stitches and the introduction of sinus forceps will probably be all the treatment required. When the infection is by non-hæmolytic streptococci or staphylococci, these simple measures are less likely to succeed, and the wound may have to be completely opened up. Late onset of pain, which was at first absent, and a temperature curve tending to rise instead of fall, are the usual indications of suppuration.

The general aspect of a patient whose wound is infected with hæmolytic streptococci is in the vast majority of cases entirely different. He is anxious, looks ill, complains of pain in his wound, often severe, refuses food, and sometimes has nausea or vomiting. His temperature and pulse are on the up grade, and on dressing his wound the skin around it for some distance will be found to be œdematous and covered with a dull red or bluish-red blush ; serum pours out from the wound, often so profusely as to saturate the dressings. No time should be lost in opening such a wound widely and beginning treatment with some antiseptic such as Carrel Dakin, flavine, or B.I.P.P.

The points which are of value in clinically distinguishing infection by hæmolytic streptococci from other conditions are, therefore : (1) general aspect and condition ; (2) pain in wound ; (3) appearance of wound and exudation of serum. If the symptoms and appearances of this virulent infection are so distinctive, it may be argued that bacteriological examination may be safely dispensed with as an adjunct to early suture of wounds. There can be no doubt that the difficulty of preparing cultures in large numbers, if such cultures are necessary in every case, must militate considerably against the use of primary or delayed primary suture during periods of active fighting. Unfortunately the symptoms are not always so clear as we have described them above in typical cases. Sometimes a patient with only a mild infection, or with no infection at all, will have severe pain in his wound, will feel sick, and look ill, and on removing the dressings a considerable exudation of serum will be found. Without the assurance of the bacteriologist that hæmolytic streptococci are absent, the surgeon must open the wound, as he is in doubt, and cannot afford to run risks. On the other hand, we have known a case heavily infected by these organisms heal by first intention without either local or constitutional reaction.

The Chart shown in *Fig.* 104 illustrates the kind of difficulty which may arise. *Cases A* and *B*, operated on the same evening, next morning presented almost identical clinical conditions. The bacteriological report indicated that *A* required immediate treatment, while *B* might safely be left alone. Without the aid of this report it is very probable that *B*'s wound might have been opened, and a good result thus spoiled.

Such experience as we have gained leads us to believe that, while the services of a bacteriologist are of the greatest advantage to the surgeon in doing this work, and that without his help the best results cannot be obtained, yet it is possible to depend on careful clinical observation alone, though in this way many wounds may have to be opened up which would heal by first intention had the required bacteriological report been available. In the absence of sufficient bacteriologists to prepare cultures for all wounds, their services should be reserved for the examination of those of the more severe type.

Dressings.—Cases which are obviously doing well are usually dressed at the end of forty-eight hours, after which it is unnecessary to change the dressings for eight or ten days, when the sutures may be removed. If there has been tension, however, it is advisable to leave the deep sutures considerably longer. Wounds which have been treated with B.I.P.P. should retain at least some of their sutures for two or three weeks, as wounds so treated appear to take longer to unite than the average. Unnecessary dressing of these wounds is harmful ; we have frequently seen patients the worse for it. Physiological rest is the most important feature of their after-treatment. It is necessary to bear in mind that the vast majority of these wounds, though they may be clinically aseptic, are not bacteriologically sterile, and this is the probable explanation of the undoubted fact that sutured wounds, if transferred to the base in their early stages, so frequently go wrong. The jolting and shaking of the journey is

sufficient, by causing slight further traumatisms, to enable already existing infection to gain the upper hand.

Massage and Movement.—Massage for the limb may be carefully begun as soon as healing is complete, but it should not at first be applied near the wound. After the third week gentle massage may be allowed round the wound, but not in cases that have had streptococcal infection, which is easily lighted up afresh even after the lapse of many weeks. In the case of flesh wounds the patient may be allowed to move his injured muscles himself as soon as the wound is soundly healed. He may be trusted not to do damage by too violent efforts. Passive movements should certainly not be allowed till after the lapse of a month in ordinary cases, and a much longer period in cases infected by streptococci. They may do much damage in lighting up sepsis, and where the original infection has been virulent they are dangerous.

Delayed Primary Suture.—The excised and cleaned wound is treated with some antiseptic, such as B.I.P.P., flavine, or dichloramine-T, and lightly packed with gauze. The sutures may be placed in position at the primary operation and left loose, or they may be inserted at the time of closing the wound. In either case the same care as in primary suture is necessary to secure perfect apposition of deep as well as superficial surfaces. The liability of open wounds to become infected with staphylococci, probably from the skin, renders it advisable to use antiseptics as a routine measure. We have employed each of the above-mentioned with success. The question of antiseptics will be further discussed under a separate heading.

Except in cases when the bacteriologist has reported the presence of hæmolytic streptococci in the first culture (taken before operation), our practice has been to close the wound in from two to four days, provided that it appears clean and healthy when dressed, and the patient's general condition is satisfactory. The suturing has been performed usually under gas and oxygen, but several operations have been satisfactorily carried out under Gwathmey's method of oral anæsthesia.

If it is decided to postpone suturing still further, a culture or smear is taken, and the wound re-dressed. Except in the presence of streptococci, our practice has been to rely on clinical indications rather than on bacteriological findings. If hæmolytic streptococci are present in the first culture, we do not attempt suture till the patient's temperature has been normal for some days, till his wound looks clean and healthy, and till smears taken from it give a count of not more than one coccus per field. This rule does not apply to amputations performed through uninfected tissue above an infected wound: the stump can usually be safely closed in two or three days. We find that a wound infected with hæmolytic streptococci does not often reach the suture stage for about fourteen days.

The healing of wounds closed a few days after the primary operation appears to us to be nearly equal to the results obtained by immediate suture.

The softness and pliability of the scars obtained by these methods, the absence of hard contracting masses of fibrous tissue and of pain and tenderness at the site of the wound, and the rapid recovery of function, form a marked contrast with the results so often seen when wounds have been allowed to heal by granulation.

After-Treatment of Compound Fractures.—From inquiries at the base and in England, we understand that fractures travel best within the first few days after operation at the C.C.S., or in their later stages, on the other hand, after some degree of union has been obtained. Patients who travel in the intermediate stages are liable to develop severe outbreaks of sepsis. We have therefore kept our compound fractures at the C.C.S. for a considerable time, in many cases till firm union has taken place.

Two huts were equipped with suspension apparatus in the following manner: 1-in. iron piping, hung by brackets, was run along the whole length of the hut, in a vertical plane 1 in. beyond the ends of the beds; on a level with this, 3½-in. by 1-in. planking, with notches cut in its upper border at 4 in. intervals, was nailed to the wall, also along the whole length of the hut. A number of movable cross-pieces were made, of 3½-in. plank, one end of which rested in the notches and the other on the iron piping. A

firm bar, which could be placed in such a position over the patient's bed as to obtain any degree of abduction required, was thus provided for suspension of the lower limb. Vertical bars were also made, with a notch to fit on to the iron piping, and of such a



FIG. 82.—Showing a hut with suspension equipment.

length that with the notch in position they reached the floor with a slight inclination away from the foot of the bed. Weight extension was obtained by means of pulleys attached to the vertical bars at any level required (*Fig.* 82).

Individual Fractures.—*Femur.*—Fractured femurs were treated on Thomas splints, generally bent opposite the knee to a greater or less extent according to the displacement to be rectified. In most cases a fixed extension was used by means of glue and strips of gauze. This was usually supplemented by weight extension attached to the end of the splint, in order to relieve pressure of the ring on the tuber ischii. In one case in which considerable flexion of the knee was necessary, and large wounds prevented the application of glue or plaster, weight extension was obtained by the use of the caliper invented by Major Besley, U.S.R.

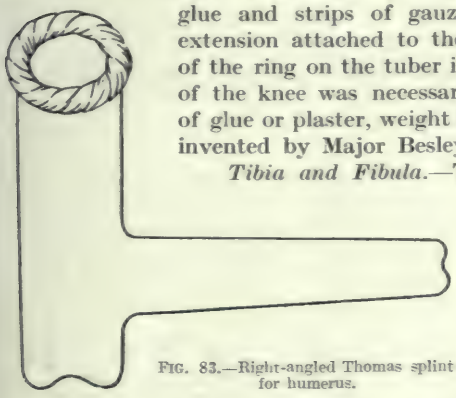


FIG. 83.—Right-angled Thomas splint for humerus.

Tibia and Fibula.—These were commonly treated on slightly flexed Thomas splints with the addition of a Sinclair foot-piece for extension. Hey Groves's skeleton inclined plane with foot-piece was also used.

Humerus and Elbow.—These fractures were always treated with the elbow flexed at right angles, generally from the beginning, and if not, after the first few days. In the early stages shutter splints were sometimes used, and the limb was suspended by flannel strips from an iron wire trapeze in the position of full abduction of the shoulder. The trapeze itself was suspended by weight and pulley. Later these fractures were put up in

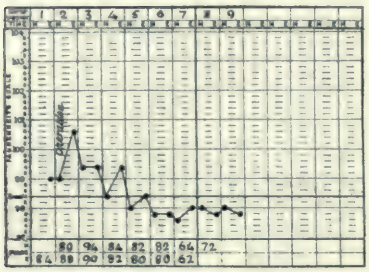


FIG. 84.—PRIMARY SUTURE (B.I.P.P.). Shell wound both buttocks; excision and suture; healing by first intention.

INFECTION: *Aerobic*, short non-hæmolytic streptococci; *anaerobic*, negative.

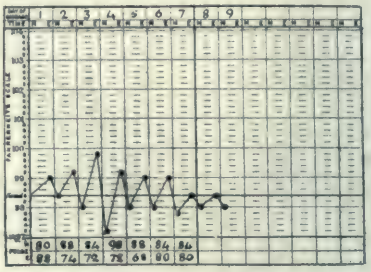


FIG. 85.—PRIMARY SUTURE (DICHLORAMINE-T). Shell wounds left thigh, and through-and-through right calf; excised and sutured; healing by first intention.

INFECTION: *Anaerobic*, gas-forming bacilli; *aerobic*, staphylococci and bacilli.

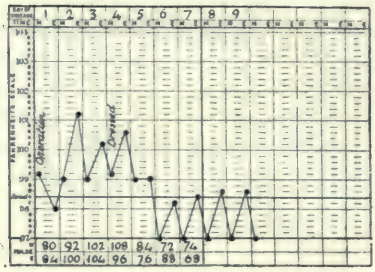


FIG. 86.—PRIMARY SUTURE (B.I.P.P.). Bullet wound right knee (not penetrating joint); excised and sutured; healing by first intention.

INFECTION: *Aerobic*, staphylococci and non-hæmolytic streptococci; *anaerobic*, negative.

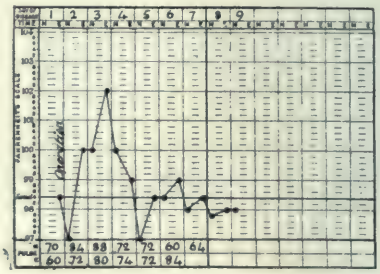


FIG. 87.—PRIMARY SUTURE (ETHER). Shell wound right thigh, track 6 in. long × 1½ in. deep; excised and sutured; healing by first intention.

INFECTION: *Aerobic*, bacilli and short non-hæmolytic streptococci; *anaerobic*, B. Welchii.

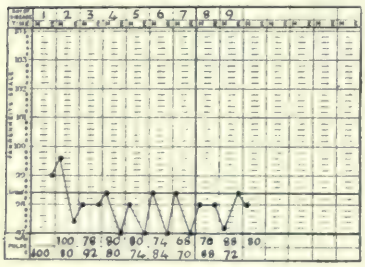


FIG. 88.—PRIMARY SUTURE (B.I.P.P.); COMPOUND FRACTURE. Shell wound foot; compound fracture 4th and 5th metatarsals, cuboid, and internal cuneiform; wound excised and left open; sutured completely on third day; complete healing.

CULTURES: Negative.

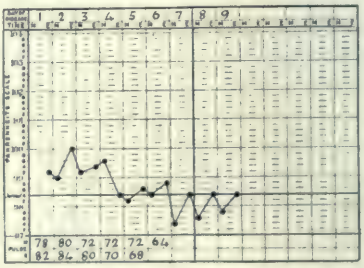


FIG. 89.—PRIMARY SUTURE AND TENDON SUTURE (B.I.P.P.); COMPOUND FRACTURE. Shell wound right ankle; compound fracture astragalus, division of tibialis anticus and extensor longus hallucis tendons; excision of wound, suture of tendons, primary suture; healing by first intention.

INFECTION: *Aerobic*, bacilli; *anaerobic*, negative.

Thomas splints bent at right angles at the elbow (*Fig.* 83), with fixed extension by means of glue and gauze strips.

Forearm.—Hey Groves's open wire splint was found satisfactory in the treatment of these fractures. By its means the position of supination is easily obtained.

If extreme care be exercised, we believe that no serious disaster should occur as the result of early suture, though to estimate accurately the amount of damage done by primary suture to a patient whose wounds are infected with virulent streptococci is a difficult matter. As far as we have seen, if the stitches are taken out in good time, little harm has resulted from the wound having been closed for a short period. It is certain, however, that undue delay in re-opening these wounds would inevitably lead to grave disasters.

The accompanying series of Charts (*Figs.* 84–104) is illustrative of the clinical course of wounds treated by these methods, and includes varying types from simple flesh wounds to severe compound fractures and amputations. Failures due to virulent infection are shown, as well as cases in which union per primam has been attained.

A number of skiagrams and drawings are also given, showing some of the wounds which have been sutured with more or less success (*Figs.* 105–125).

II. STATISTICAL SUMMARY.

1. **General.**—The total number of wounded men admitted to the C.C.S., from Dec. 27, 1917, to March 1, 1918, was 498.

Cases unsuitable for suture	195 = 39·2 per cent
Cases entered on list for suture ..	303 = 60·8 „ „

Of the 303 cases entered on the research list, primary or subsequent suture of their wounds was actually carried out in 285.

In 13 cases, it was found impossible to close the wounds within a reasonable time after operation, on account of loss of tissue or of severe sepsis.

Of the patients on the research list, 7 died, 4 before any attempt had been made to suture their wounds, and 3 subsequently to complete or partial suture.

The *mortality* amongst the 285 cases whose wounds were sutured amounted therefore to 3, or about 1 per cent.

Total cases sutured			285
Cases still incomplete for report	13		
Secondary sutures not included in report	8		
	—	21	
Total cases reported on (including 3 patients who died)			264

The number of wounds in the 264 cases amounted to 315; for the purposes of this report it is convenient to consider each wound as a separate entity, and the following figures refer to wounds and not to individual patients (with the exception of No. 2).

2. **Interval between Wound and Operation.**—

Average interval in all cases	11·7 hours
„ „ in successful cases ..	10·7 „
„ „ in failures	12·1 „

The earliest successful primary suture was performed two and a half hours after infliction of the wound, and the latest (for a slight wound of the arm) thirty-seven hours afterwards.

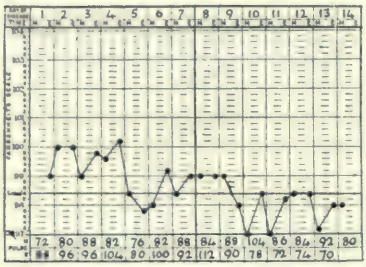


FIG. 90.—PRIMARY SUTURE (B.I.P.P.); COMPOUND FRACTURE. Shell wounds elbow and buttock; compound fracture humerus and ulna into joint; buttock wound excised and sutured; elbow wound excised and fracture cleaned; healing by first intention in both cases.

INFECTION: Elbow—*Anaerobic*, bacilli without gas; *aerobic*, long streptococci (non-hæmolytic). Buttock—*Anaerobic*, B. Welchii, streptococci; *aerobic*, short non-hæmolytic streptococci, staphylococci.

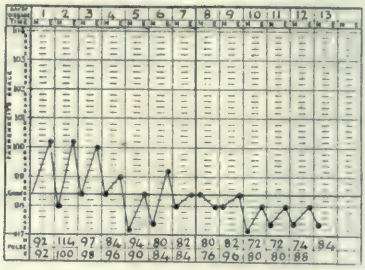


FIG. 91.—PRIMARY SUTURE (ETHER); COMPOUND FRACTURED HUMERUS. Severe comminuted fracture of humerus, with wounds of arm and forearm; wounds excised and fracture cleaned, complete suture; healing by first intention.

INFECTION: *Anaerobic*, bacilli without gas; *aerobic*, negative.

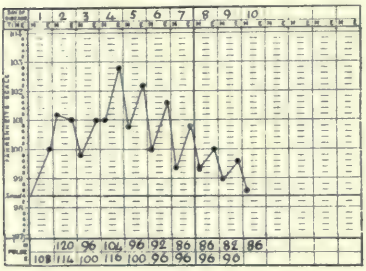


FIG. 92.—PRIMARY SUTURE (SALINE); DELAYED PRIMARY SUTURE (FLAVINE). Shell wounds left thigh and buttock, and left arm; wounds excised; buttock wound left open and packed with flavine; arm wound sutured without antiseptic; buttock wound sutured after 48 hours; both wounds healed completely.

INFECTION: Arm wound—negative. Buttock wound—*Anaerobic*, gas-forming bacilli; *aerobic*, non-hæmolytic streptococci.

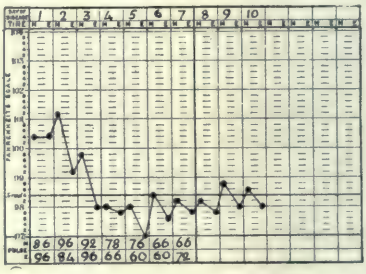


FIG. 93.—DELAYED PRIMARY SUTURE (FLAVINE). Through-and-through wound of calf; excised and left open, packed with flavine gauze; sutures inserted at primary operation but not tied; sutures tied 48 hours later; complete healing.

INFECTION: *Anaerobic*, gas-forming bacilli; *aerobic*, long-chained non-hæmolytic streptococci.

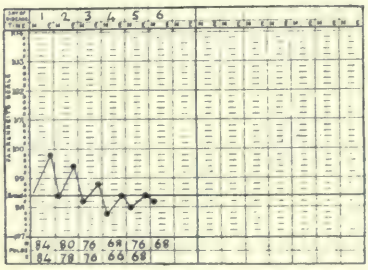


FIG. 94.—DELAYED PRIMARY SUTURE (FLAVINE). Shell wound forearm, foreign body firmly embedded in ulna; wound excised and foreign body removed, left open and dressed with flavine gauze; sutured on third day; healing by first intention.

INFECTION: *Anaerobic*, cocci; *aerobic*, non-hæmolytic streptococci.

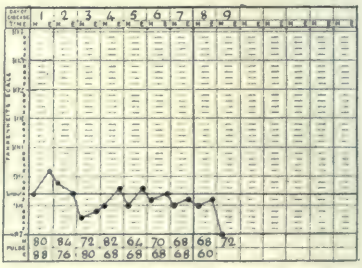


FIG. 95.—DELAYED SUTURE; COMPOUND FRACTURED HUMERUS. Shell wound of arm; compound fracture of humerus; wound excised and left open; flavine pack third day; suture; healing by first intention.

INFECTION: *Anaerobic*, cocci; *aerobic*, negative.

3. Primary Suture.—

Complete primary union	146	= 80 per cent
Partial „ „	33	
Failures	45	= 20 „ „
Total wounds	224	

4. Delayed Primary Suture.—

Complete primary union	78	= 96 per cent
Partial „ „	16	
Failures	4	= 4 „ „
Total wounds	98	

5. Comparison of Results of the Use of Antiseptics, etc.—

	No Antiseptic.	
Primary suture:	Primary union (complete or partial)	37
	Failures	4
	Total wounds	41
	Soap.	
Primary suture:	Primary union (complete or partial)	22
	Failures	7
	Total wounds	29
	Ether.	
Primary suture:	Primary union (complete or partial)	46
	Failures	9
	Total wounds	55
	Flavine.	
Immediate suture:	Primary union (complete or partial) ..	24
	Failures	4
	Total wounds	28
Delayed suture:	Primary union (complete or partial)	60
	Failures	3
	Total wounds	63
	B.I.P.P.	
Immediate suture:	Primary union (complete or partial) ..	52
	Failures	16
	Total wounds	68
Delayed suture:	Primary union (complete or partial)	31
	Failure	1
	Total wounds	32

The number of wounds treated by dichloramine-T is at present so few that we have not included them in the statistics of antiseptics.

These figures are, obviously, too small to form a basis for comparison of the value of the different substances used. Large numbers would be necessary in order to eliminate coincidence, seeing that the severity of the wounds and the nature of the infection are so variable. Further, the natural tendency of every surgeon is to use the antiseptic in which he has the most confidence in the treatment of severe wounds. Thus, with a few exceptions, only the slighter wounds have been treated without antiseptics, and this may account for the results without antiseptics being the best (90 per cent of successes).

As regards immediate suture, flavine and ether come next (86 and 84 per cent of successes), then soap and B.I.P.P. (about 76 per cent). No particular importance can, we think, be attached to these figures.

Regarding delayed suture, the figures, as far as they go, show a decided superiority

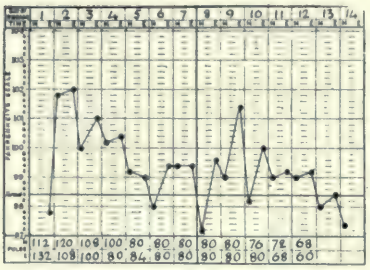


FIG. 96.—DELAYED PRIMARY SUTURE (FLAVINE); AMPUTATION OF THIGH. Shell wounds both lower limbs; on left side severe compound fractured femur and compound fractured tibia, with divided posterior tibial artery; on right side compound fractured tibia. Amputation through junction of upper and middle third of left thigh by long antero-external and short postero-internal flaps; wound packed with flavine gauze and left open; right leg, wounds excised and left open. Suture of amputation wound on third day. Complete healing; good painless stump three weeks later. Right leg left to granulate owing to loss of skin.

INFECTION: *Anaerobic*, gas-forming bacilli; *aerobic*, bacilli and short non-hæmolytic streptococci.

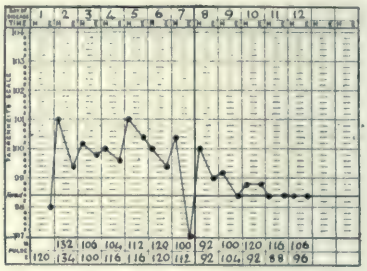


FIG. 97.—DELAYED SUTURE; COMPOUND FRACTURED HUMERUS; AMPUTATION OF THIGH; THROUGH-AND-THROUGH WOUND BUTTOCK. Shell wounds arm—compound fractured humerus; knee—joint shattered; and buttock. Excision of wound in arm, cleaning of fracture; amputation through knee-joint; both wounds left open and packed with flavine gauze; excision of buttock wound, left open with B.I.P.P. pack. Third day, re-amputation of thigh, lower third; suture. Fifth day, arm and buttock wounds sutured. Complete healing.

INFECTION: Arm—negative. Leg—*Anaerobic*, gas-forming bacilli; *aerobic*, hæmolytic streptococci and bacilli. Buttock—no culture.

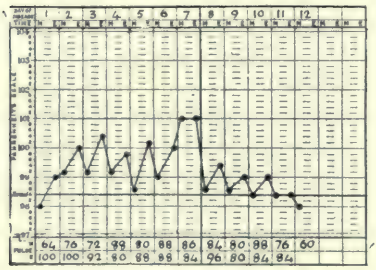


FIG. 98.—DELAYED SUTURE; COMPOUND FRACTURED TIBIA AND ULNA. Shell wounds of arm and leg; compound fracture of tibia and ulna; wounds excised and left open with B.I.P.P. pack; arm sutured on fifth day, leg on 7th day; complete healing.

INFECTION: *Anaerobic*, gas-forming bacilli; *aerobic*, non-hæmolytic streptococci.

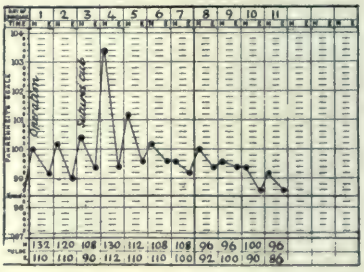


FIG. 99.—DELAYED SUTURE; SYME'S AMPUTATION. Bullet wound foot; comminution of tarsal bones; Syme's amputation; wound left open (B.I.P.P.); sutured third day; healing by first intention; excellent stump.

INFECTION: *Anaerobic*, cocci; *aerobic*, staphylococci and non-hæmolytic streptococci.

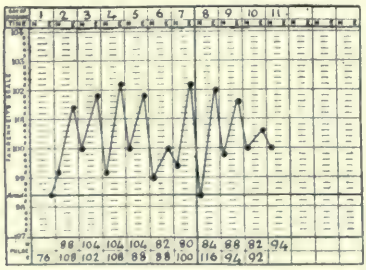


FIG. 100.—FAILURE OF PRIMARY SUTURE. Shell wound, through-and-through, of right leg, with explosive exit; excised and sutured (ether); complete failure, all sutures removed on third day.

INFECTION: *Aerobic*, long-chained hæmolytic streptococci; *anaerobic*, present.

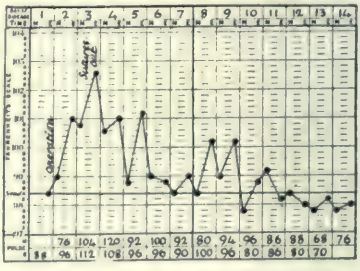


FIG. 101.—FAILURE OF PRIMARY SUTURE. Small shel wound right thigh; wound excised completely with foreign body in it (ether); complete failure, all sutures taken out on third day.

INFECTION: Long-chained hæmolytic streptococci.

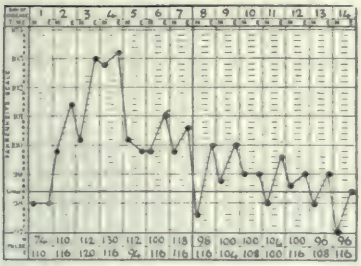


FIG. 102.—FAILURE OF PRIMARY SUTURE; STREPTOCOCCAL INFECTION OF KNEE-JOINT. Bullet wound over head of right fibula: no evidence, *x*-ray or otherwise, of communication with knee-joint; wound excised, with bullet, and sutured without antiseptic. Culture report, infection by hæmolytic streptococcus. Wound opened up immediately. Third day, effusion into knee-joint; fluid withdrawn by syringe contained hæmolytic streptococci. Fourth day, joint opened by separate incision, washed out with flavine, and sutured. Recovery; superficial suppuration in operation wound.

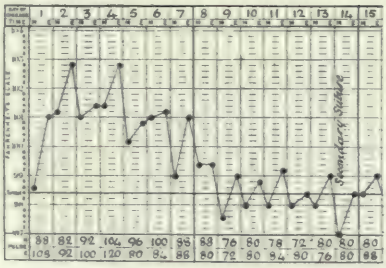


FIG. 103.—FAILURE OF PRIMARY SUTURE: SUBSEQUENT SUCCESSFUL SECONDARY SUTURE. Through-and-through wound of thigh, with extensive laceration of hamstrings and exposure of sciatic nerve; track excised as far as possible, anterior wound sutured, posterior wound left open; suppuration, removal of stitches on third day, treated as an open wound with B.I.P.P.; sutured on fourteenth day; complete healing.

INFECTION: *Anaerobic*, gas-forming bacilli; *aerobic*, bacilli, streptococci (non-hæmolytic).

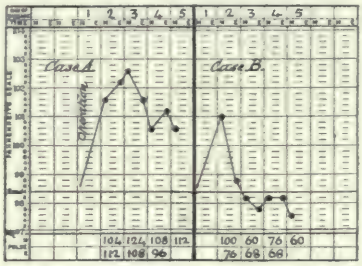


FIG. 104.—CONTRAST OF WOUND INFECTED BY HÆMOLYTIC STREPTOCOCCUS WITH NON-INFECTED WOUND.
Case A.—Through-and-through wound thigh; excised and sutured (flavine).
Case B.—Through-and-through bullet wound forearm, compound fracture ulna; excised and sutured (soap).
The condition of these two patients on the morning following operation was almost identical as regards temperature and pulse; both were in pain, both were sweating and feeling ill. The culture from *A* showing hæmolytic streptococci, his wounds were at once opened and found to be acutely septic. *B's* culture being reported negative, the wound was not even dressed; result, healing by first intention.

over the results given by immediate suture. The explanation of this will be referred to under "Bacteriology in Relation to Results."

6. Compound Fractures treated by Suture.—Of compound fractures, 71 have been sutured either immediately or after the lapse of a few days.

BONE	IMMEDIATE SUTURE			DELAYED SUTURE		
	Total	Success	Failure	Total	Success	Failure
Upper Extremity						
Humerus	4	3	1	8	7	1
Elbow (humerus and ulna)	2	1	1	—	—	—
Ulna	2	1	1	3	3	—
Radius	2	1	1	2	2	—
Metacarpus	2	2	—	2	1	1
Lower Extremity						
Femur	9	3	6	1	—	1
Tibia and Fibula	2	1	1	1	1 (partial)	—
Tibia	9	7	2	6	6	—
Fibula	2	2	—	3	3	—
Patella	1	1	—	—	—	—
Tarsus	2	2	—	3	3	—
Metatarsus	—	—	—	4	4	—
Phalanges of toes	—	—	—	1	1	—
Totals	37	24 (65 per cent)	13 (35 per cent)	34	31 (90 per cent)	3 (10 per cent)

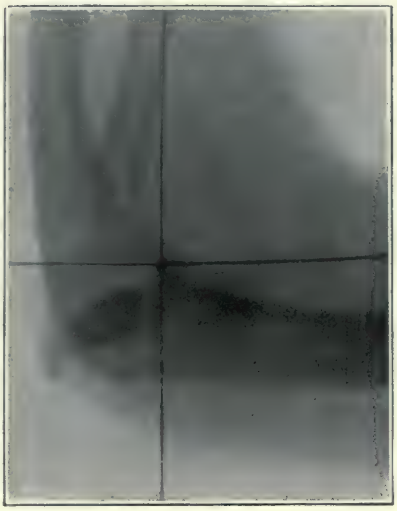


FIG. 105.—Fracture of humerus and ulna; piece of metal in elbow-joint partly embedded in ulna. Primary suture (B.I.P.P.). Healed by first intention.

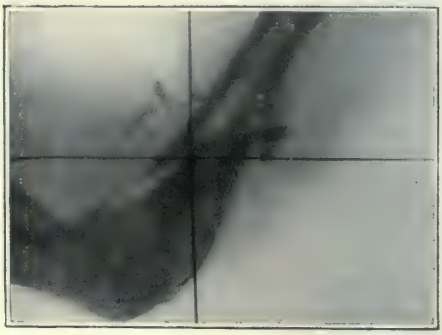


FIG. 106.—Comminution of humerus. Primary suture (B.I.P.P.). Healed by first intention.

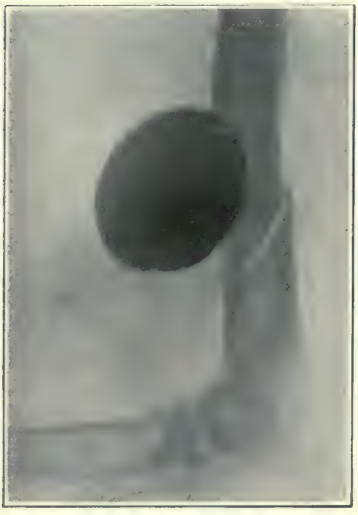


FIG. 107.—Humerus fractured by impact of large fragment of shell which entered forearm and passed into upper arm. Primary suture (B.I.P.P.). Healed by first intention



FIG. 108.—Comminution of second metatarsal. Delayed suture (B.I.P.P.). Complete healing.

7. Wounds of Joints.—

Elbow.—2 cases.

Both these were compound fractures of the humerus and ulna involving the joint: both were treated by primary suture—one healed by first intention, the other suppurated, but the patient left the C.C.S. in good condition with his wound granulating.

Ankle.—3 cases.

a. Through-and-through wound involving the ankle-joint—compound fracture of astragalus and division of the tibialis anticus and extensor longus hallucis tendons; suture of tendons and immediate closure of wound; primary union; good movement of joint.

b. Through-and-through wound involving the ankle-joint—compound fracture of astragalus; delayed suture; healing per primam; good movement of the joint.

c. Compound fracture of the lower end of the tibia involving joint; immediate suture; primary union.

Knee.—17 cases.

a. Fracture of one or more bones entering into the joint. 11 cases. These were treated by immediate suture: 6 were completely successful; 5 suppurated—amongst the latter 3 recovered without loss of limb, and 2 were amputated. One of the amputation cases died of shock and toxæmia from an acute spreading streptococcal infection of the intermuscular planes of the thigh.

b. Without fracture, 6 cases. Of these, 5 were treated by immediate suture, including one in which the patella was divided vertically in order to remove a piece of metal lying in the intercondyloid space behind the crucial ligaments; all these healed by first intention. One case in which there was extensive gas infiltration of the muscles of the thigh was treated by suture of the capsule, the external wound being left open. Sloughing of the sutured capsule took place after some days, allowing infection to spread into the joint; amputation became necessary, after which a good recovery took place.

8. Amputations.—

Immediate Suture.—6 cases.

Thigh 2; leg 2; toes 1; fingers 1. Of these cases, 4 healed per primam, and 2 were failures (1 thigh and 1 leg).

Delayed Suture.—17 cases.

Of these, 12 healed completely by first intention, and 5 with slight suppuration; none failed.

Healed by primary union completely.		*Healed with slight suppuration.*	
Thigh by musculo-cutaneous flaps	4	Thigh	2
Carden	2	Leg	1
Stokes-Gritti	1	Syme	1
Leg	3	Arm	1
Syme	1		—
Forearm	1	Total	5
Total	12		

9. Deaths amongst Patients on Research List.—

Cases Sutured.

1. Compound fractured femur; anterior wound partly sutured; posterior wound left widely open; acute gas infection.

2. Compound fracture of the inner condyle of femur and tuberosity of tibia involving the knee-joint; suture; acute infection by hæmolytic streptococci; amputation; death from shock and toxæmia.

3. Shell wound of thigh exposing the femoral vessels; cleaned and left open; partial delayed suture on seventh day; secondary hæmorrhage; amputation; death from shock.

Cases not Sutured.

1. Comminuted fracture of left leg, and multiple wounds; amputation; death from shock.

2. Gunshot wound of thigh; excised; while coming round from the anæsthetic



FIG. 109.—Comminuted fracture of tibia; foreign body embedded in fracture. Delayed suture (B.I.P.P.). Complete healing.



FIG. 110.—Comminuted fracture of humerus. Delayed suture (flavine). Complete healing.

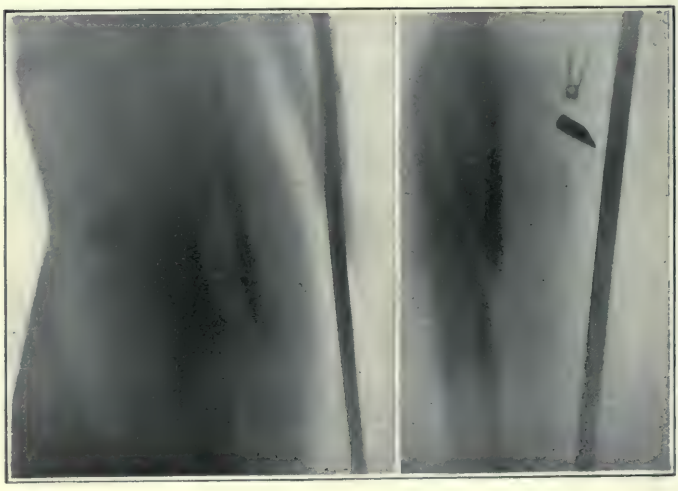


FIG. 111.—Femur fractured by bullet. Missile removed; wound sutured without antiseptic; track not touched. Healed by first intention. Bone well united without shortening in five weeks.

patient vomited and inhaled a large quantity of meat into his trachea; immediate tracheotomy: death six hours later from epileptiform convulsions; post-mortem revealed collapse of both lungs.

3. Shattered knee-joint and multiple wounds; transfused with blood twice; amputation; wounds infected with hæmolytic streptococci; death after three weeks from general streptococcal infection

4. Compound fracture of femur; wound excised and left open; infection by hæmolytic streptococci; death from septicæmia.

10. **Bacteriology in Relation to Results.**—Of 224 wounds sutured primarily, cultures were made in 215. Of the latter, 21 (9·7 per cent) were negative; all these healed completely by first intention. The remaining 194 (90·3 per cent) were infected with anaerobes, streptococci, or other organisms mentioned in the bacteriologists' report.

The relationship of the individual organisms to success or failure is in most cases impossible to determine exactly, as the infection is generally mixed. In the 194 infected wounds treated by immediate suture, anaerobes occurred in 119 (61·3 per cent), non-hæmolytic streptococci in 62 (32·4 per cent), hæmolytic streptococci in 20 (10·3 per cent), and other organisms in 95 (48·9 per cent).

Infection	No. of Wounds	Healed by Primary Union	Failed
Anaerobes	119	88 (73·9 per cent)	31 (26·1 per cent)
Non-hæmolytic streptococci ..	62	44 (70·9 per cent)	18 (29·1 per cent)
Hæmolytic streptococci	20	1 (5·0 per cent)	19 (95·0 per cent)
Other organisms	95	64 (67·2 per cent)	31 (32·8 per cent)

The general conclusion to be drawn from these figures is that wounds infected by the hæmolytic streptococcus nearly always become septic, while a large proportion of wounds infected in other ways heal by first intention. Failure took place in only one case of primary suture which was infected by anaerobes alone; in this case a muscle flap used for filling a bone cavity sloughed and a gaseous abscess developed in the wound.

Streptococcal Infection.—Only one case infected by hæmolytic streptococci (a small wound penetrating the knee-joint without damage to bone) healed by first intention; all the rest suppurated, many of them violently and with severe constitutional disturbance. Infections by non-hæmolytic streptococci as a general rule appear to be less virulent. As shown by the above figures, a considerable proportion of wounds containing these organisms healed by first intention. When failure occurs, the suppuration is usually milder than that characteristic of the hæmolytic streptococcus. Sometimes, however, the non-hæmolytic streptococcus, in association with other organisms, appears to set up sepsis of a very severe type. Although only one case infected by these streptococci alone has failed to heal by first intention, our clinical experience leads us to look on their presence with suspicion when anaerobes and other bacteria accompany them.

Delayed Primary Suture.—The 4 cases of delayed suture which failed were infected as follows:—

1 wound with anaerobes and non-hæmolytic streptococci
1 ,, ,, ,, ,, hæmolytic streptococci
2 wounds ,, ,, ,, staphylococci

The advantage which delayed suture offers as compared with immediate suture depends on the knowledge of virulent infection gained during the interval while the wound is open. Even if a bacteriological examination has not been made, the appearance of a virulently infected wound when first dressed forty-eight or seventy-two hours after operation is usually distinctive, and it is not sutured. In this way the proportion of failures after delayed suture should be reduced to a very small percentage.

While no antiseptic which we have tried, either in open or closed wounds, appears to us to have any appreciable effect on the growth of the hæmolytic streptococcus, the

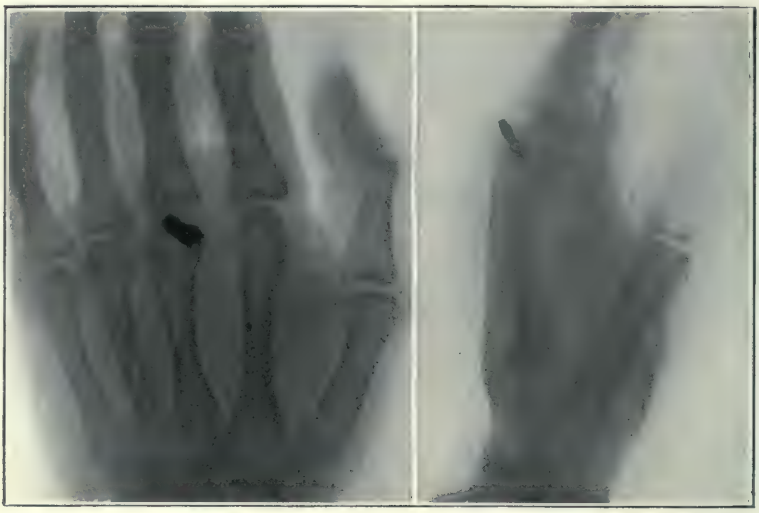


FIG. 112.—Fracture of head and splitting of shaft of third metacarpal. Primary suture (soap). Healed by first intention.

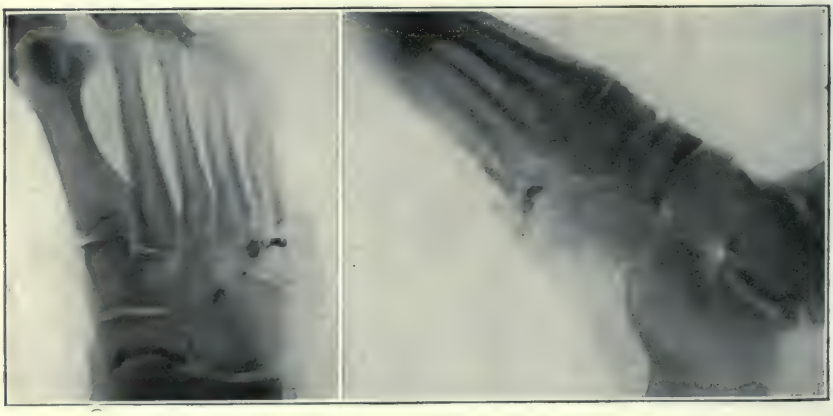


FIG. 113.—Compound fracture of fourth and fifth metatarsals, external cuneiform, and cuboid. Delayed suture (B.I.P.P.). Complete healing.

following statement of the results of the use of flavine points to the probability that chemical antiseptics, when applied to the surface of open wounds infected with bacteria of less virulence, may fulfil a useful function.

11. **Use of Flavine in Delayed Suture.**—In 35 cases in which the wound was packed with gauze soaked in flavine solution (1–1000), and in which the original culture showed the presence of infection (other than hæmolytic streptococci), smears taken from the wound on the second or third day prior to suture were examined, and in 31 cases no organisms could be found. It appears probable, therefore, that flavine used in this way acts definitely as a germicide. We have unfortunately no control experiments on wounds left open and packed with gauze without the addition of any antiseptic.

We have found it advisable to discontinue the use of flavine solution after four or five days, as wounds treated continuously with this substance for longer periods tend to become covered with a layer of coagulated lymph or necrosed tissue in which bacterial growth appears to flourish.

Used in the early stages and for a limited time, flavine, in our experience, gives satisfactory results.

12. **Sterility of Bullet Tracks.**—We have found that the narrow track of a bullet which has passed into or through a limb, without producing an 'explosive' effect by spinning or striking a bone, is usually sterile, and that operation on wounds of this type is unnecessary.

Further, we have found that where the entry wound and part of the track are clean and narrow, while the exit is lacerated, only the exit wound is likely to be infected. In such a case operation should be limited to a careful cleansing of the exit wound, damaged tissue being removed only till the orifice of the narrow track is exposed. A culture taken by introducing a swab into the latter will probably be negative, and this part of the wound need not be interfered with.

III. BACTERIOLOGICAL REPORT.

By Captain Adrian Stokes and Major W. H. Tytler.

Collection of Material.—The material was collected from the wounds at the time of operation, after the skin surface had been cleansed with salt solution, but before any antiseptic had been applied, and before the interior of the wound had been disturbed. A guarded swab was used, made by placing a long stout wire wrapped at the end with cotton-wool in the ordinary way inside a narrow glass tube open at both ends and about half the length of the swab wire. The whole was sterilized in a plugged test-tube (see *Fig.* 81). For use, the tube, with the swab still inside, was introduced into the depth of the wound, avoiding contamination from the wound edges, the swab was pushed out of the tube, thoroughly rubbed about in the wound, and again withdrawn within the tube before removing the latter from the wound. The tube and swab were replaced in the test-tube and sent to the laboratory.

Cultural Methods.—After flaming the distal end of the guard tube, the swab was pushed out, and first streaked in several lines over the surface of a blood-agar plate. It was then thoroughly washed out in a test-tube containing about 3 c.c. of sterile salt solution. From this emulsion aerobic and anaerobic cultures were made. Whenever circumstances permitted, the cultures were set up immediately on the receipt of the infected swab.

Aerobic Cultures.—In addition to the blood-plate, about ½ c.c. of the emulsion from the swab was inoculated with a pipette into a trypsin-broth tube, the remainder being used for anaerobic cultures. The object of the blood-plate was to obtain early evidence of the presence of hæmolytic streptococci. The broth culture and plate were examined after sixteen to twenty hours' incubation. In the great majority of cultures from which a hæmolytic streptococcus was obtained, the presence of this organism was definitely evident on examination of the original blood-plate. The same was true in less degree of non-hæmolytic streptococci, although there was some danger of mistaking other organisms—particularly *M. tetragenes*—for such streptococci Smears were made from the

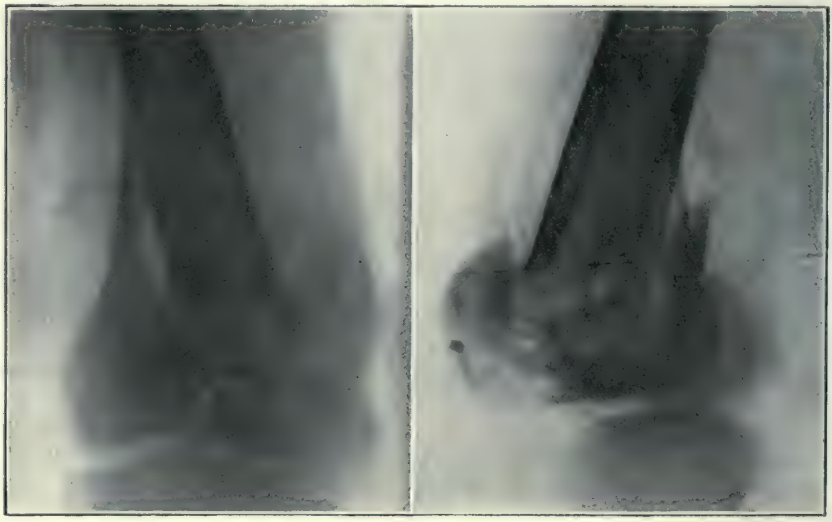


FIG. 114.—Severe comminuted fracture of lower end of femur and patella. Removal of patella and loose fragments from condyles; immediate suture (B.I.P.P.). Healed by first intention, with the exception of a slight local suppuration where a hæmatoma had to be evacuated.

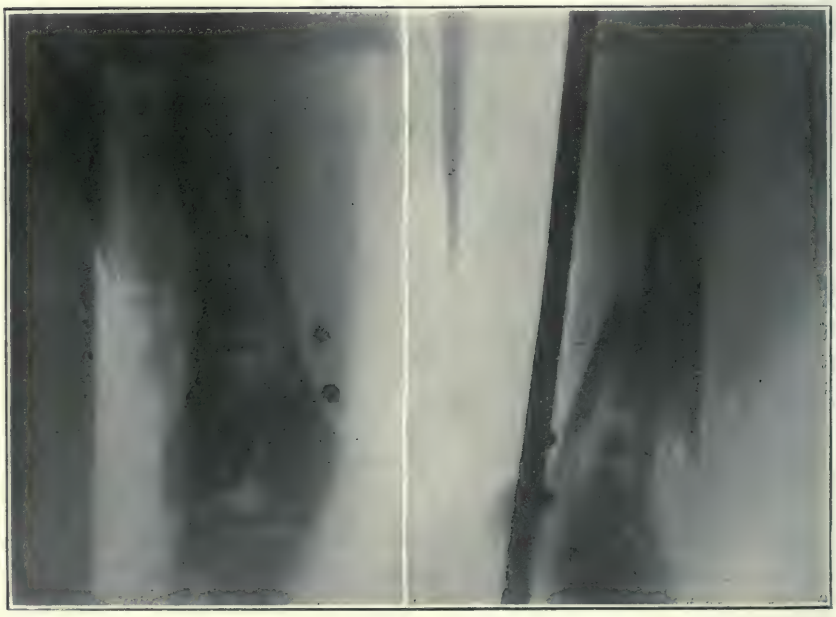


FIG. 115.—Severe fracture of femur into knee-joint, which was widely opened. Primary suture (without antiseptic). The limb becoming distended with gas, the sutures were removed from the posterior wound after 24 hours, and a pack of gauze, soaked in flavine, was inserted; 48 hours subsequently this wound was again sutured. Staphylococcal infection of the posterior wound took place, causing suppuration. The anterior wound remained closed.

N.B.—In this case, and in that shown in *Fig.* 114, the choice lay between closure of the wound and amputation. We have reason to believe that sometimes a limb may be saved by early suture of the wound, which under the usual open treatment would certainly be lost.

broth cultures, and the organisms present, as well as those on the plate whose nature was evident, were reported to the surgeons. In most cases, and in all cases where the broth showed streptococci and the plate none, the broth culture was plated on blood-agar. In about half of all cultures the broth was again examined after two days' growth, but in only one instance was a streptococcus (in this case hæmolytic) found which had not been evident at the first examination.

In all cultures the presence or absence of streptococci, and the nature of those present, were determined, and the other aerobes present were also recorded in so far as their nature was evident from the plate and smear. In a consecutive series of 165 wounds the aerobic cultures were worked out as fully as possible, each type of colony on the original plate and on the plate from the broth culture being picked off and determined within the limits of the classification given in *Table* 4.

Anaerobic Cultures.—One to two c.c. of the emulsion made from the swab was planted on Robertson's meat medium. After incubation for sixteen to twenty-four hours the culture was examined microscopically after noting the presence or absence of gas production. The result was reported as "bacilli with gas," "bacilli with no gas," and so on. Those showing bacilli with gas formation were regarded as positive for anaerobes, and the total figures given in *Tables* 2 and 3 are made up on this basis. The bacilli with no gas formation were regarded, after some experience, as aerobes, even where no growth occurred in aerobic culture. Usually, in such cases, aerobic bacilli were obtained on the original plate or on the plate from the broth culture. About two-thirds of all cultures which showed gas formation were further investigated as follows :—

After the first examination, a subculture was made in bulk on milk and an anaerobic plate was made. After experience gained in the isolation of fifteen strains of *B. Welchii* by repeated plating and rapid passage through fluid media, it was possible to recognize with a considerable degree of certainty the colonies of *B. Welchii*. The cultures recorded in *Table* 6 as containing *B. Welchii* are those which produced both typical colonies and a typical 'stormy fermentation' clotting in the milk tubes.

The positive milk cultures were then further incubated for five to seven days, heated to 80° C. for fifteen minutes, and subcultured into meat tubes, which were then incubated for three days to allow spore-bearing organisms to grow out. These subcultures were then examined and plated. After three days' incubation the plates were picked, and each type of colony was subcultured anaerobically and also aerobically to eliminate aerobic sporers.

The figures given in *Table* 6 for anaerobic sporers represent only those cultures in which the final results have been obtained up to the moment of making up the statistics. There remain a series of cultures which are still under investigation.

The percentage of spore-bearing anaerobes found is smaller than in examinations carried out at the base. The explanation of this is obviously that, in the early examination, sporers, which are more slow-growing organisms than *B. Welchii* and the saccharolytic anaerobes, have not had time to multiply sufficiently to be secured in culture.

The types of anaerobes isolated in the course of the present work include *B. Welchii*, *B. sporogenes*, *Vibrion septique*, *B. phallax*, *B. tertius*, *B. histolyticus*, *B. aerofetidus*, and several strains as yet unidentified.

Table 1.—Material Examined.

Total cases examined = 304 {
of which 257 had 1 wound
,, ,, 37 ,, 2 wounds
,, ,, 6 ,, 3 ,,
,, ,, 4 ,, 4 ,,

Total wounds examined = 365.

From 289 of these 1 culture only was examined
,, 51 ,, 2 cultures were examined
,, 22 ,, 3 ,, ,, ,,
,, 2 ,, 4 ,, ,, ,,
,, 1 ,, 5 ,, ,, ,,

Total specimens cultured = 470.



FIG. 116.—Shell wound of leg; comminuted fracture of tibia and fibula, division of anterior tibial artery. Wounds excised, cleaned, and left open. Onset of acute gas gangrene 39 hours subsequent to operation; vibrion septique found in bullæ in wound and in blood-stream.



FIG. 117.—Amputation at site of election by lateral flaps for condition shown in *Fig.* 116. Four days later gangrene appeared in flaps; culture showed presence of vibrion septique. A Garden amputation was done, the flaps being left unsutured, and the wound packed with iodine gauze.

Table 2.—First Cultures examined both for Aerobes and Anaerobes (343 Wounds).

Aerobes Present	Aerobes Absent	Anaerobes Present	Anaerobes Absent	Both Present	Both Absent
300 87·8 per cent	43 12·2 per cent	183 53·3 per cent	160 46·7 per cent	160 46·7 per cent	26 7·6 per cent



Fig. 118.—Carden's amputation referred to in *Fig.* 117 sutured 48 hours after operation. This wound healed by first intention, with the exception of some dry gangrene of the margin of the anterior flap. Patient made an excellent recovery.

Table 3.—Total Cultures Examined for Aerobes and Anaerobes Respectively.

Total Cultures	Aerobes		Total Cultures	Anaerobes	
	Present	Absent		Present	Absent
1st : 365	310 (85 per cent)	55 (15 per cent)	1st : 338	172 (50·9 per cent)	166 (49·1 per cent)
2nd : 76	53 (70 per cent)	23 (30 per cent)	2nd : 69	19 (27·5 per cent)	50 (72·5 per cent)
3rd : 25	21 (84 per cent)	4 (16 per cent)	3rd : 25	7 (28·0 per cent)	18 (72·0 per cent)

Table 4.—Aerobic Cultures in which as far as possible all Organisms were determined. (*Includes negative cultures occurring in the series.*)

Total Cultures	Negative		Hæmolytic Streptococci		Non-hæmolytic Streptococci		White Staphylococci		Yellow Staphylococci	
	No.	per cent	No.	per cent	No.	per cent	No.	per cent	No.	per cent
1st: 165	23	13·9	30	18·2	64	38·8	80	48·5	23	14
2nd: 60	19	31·6	13	21·6	8	13·3	18	30	9	15
3rd: 19	2	10·5	8	42·1	2	10·5	4	21	7	36·8

Total Cultures	Tetragenes		Diphtheroids		Gram-negative Cocci		Gram-negative Bacilli		Gram positive Bacilli	
	No.	per cent	No.	per cent	No.	per cent	No.	per cent	No.	per cent
1st: 165	22	13·3	12	7·2	15	9	38	23	59	35·7
2nd: 60	1	1·6	2	3·3	4	6·6	6	10	8	13·3
3rd: 19	0	—	0	—	1	5·2	5	26·3	1	5·2

Table 5.—Cultures Examined for Streptococcus.

Total Cultures	Hæmolytic Streptococci		Non-hæmolytic Streptococci		Total Streptococci	
	No.	per cent	No.	per cent	No.	per cent
1st: 365	54	14·8	104	28·6	15	43·4
2nd: 77	15	19·5	13	16·9	28	36·4
3rd: 26	19	34·6	4	15·4	23	40

Table 6.—Anaerobic Cultures showing Bacilli with Gas, examined for B. Welchii and Sporers.

Total Cultures Examined	B. Welchii		Anaerobic Sporers	
	No.	per cent	No.	per cent
102	94	92	—	—
45 (for sporers)..	—	—	21	46

OBSERVATIONS ON THE ABOVE TABLES.

Table 2.—The figures for 'aerobes present' include twelve cultures which showed bacilli with no gas production in the meat tube, but which showed no growth on the aerobic cultures. Experience justifies the view that such bacilli are nearly always aerobes.

The cultures recorded as 'anaerobes present' are those showing bacilli with gas formation in the meat tube. These figures are undoubtedly too low, as time and personnel did not permit the exhaustive examination of more than about a half of all anaerobic cultures, and the results in the remainder were those recorded after sixteen to twenty hours' incubation only.

Table 3.—The same remarks apply to these figures as to those in *Table* 2. First cultures are those taken before operation, as described above. Second cultures were usually made at the time of first dressing; in all but six cases the interval after operation was between one and seven days, with an average of three days. Third cultures were made from four to fourteen days after operation, averaging eight days.

The wounds from which second and third cultures were made were those which were left open—that is, the more serious wounds—and so the percentages, by comparison with the first cultures, which included all wounds, are much too high. The same remarks



FIG. 119.—Explosive exit wound in arm caused by rifle bullet, 13 hours after infliction. Comminuted fracture of humerus.

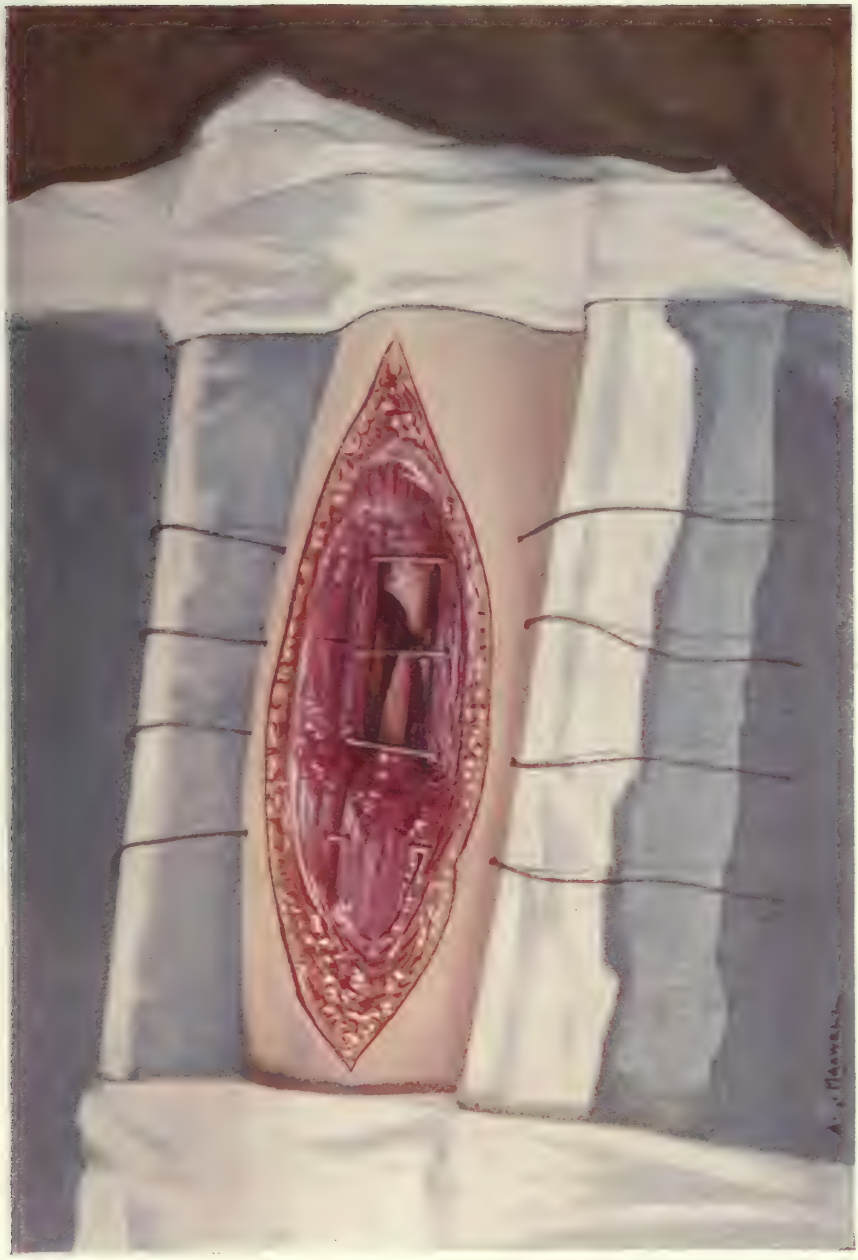


FIG. 120.—Wound shown in *Fig.* 119 after excision of damaged muscle and cleaning of the fracture, and after a further interval of 48 hours, during which it was packed with gauze soaked in soap solution. Deep sutures of 'tipped' silk in position.

apply to *Tables* 4 and 5, and particularly to the figures for hæmolytic streptococci, since wounds which were found to contain these organisms were usually opened up and further cultures made.

Table 4.—To the figures for bacilli in the first cultures must be added four cultures which showed bacilli with no gas production in the meat tube with no growth aerobically.

The figures for white staphylococci are for those cultures which remained white after twenty-four to forty-eight hours in subculture. Of a series of 100 such organisms which were further grown out over a period of a month or more, 20 per cent ultimately produced yellow pigment. The necessary correction, however, is not as great as 20 per cent, since many of the wounds from which such organisms came had already yielded yellow staphylococci, and in some of the wounds where several strains were grown out, some became yellow while others remained white.



FIG. 121.—Closure of wound shown in *Fig.* 120. The wound healed by first intention.

IV. CONCLUSIONS.

The number of cases is too small to enable us to form definite conclusions on points of detail, such as the value, absolute or relative, of antiseptics in the closure of infected wounds.

We have been able to confirm fully the statement already made by French surgeons, that of the organisms commonly found in gunshot wounds the hæmolytic streptococcus is by far the most virulent. Although it has been found to be present only in about 15 per cent of the cultures in this series, yet we believe that in the later stages of open wounds it is far more common. In the absence of this organism the vast majority of wounds can be closed and made to heal by first intention, in spite of the presence of other infections.

So far we have not found that any antiseptic we have tried can be said to have any palpable effect on wounds infected by these organisms. They appear to penetrate



FIG. 122.—High-explosive shell wounds of thigh, 13 hours after infliction.



FIG. 123.—Dissection of thigh required to clear away dead and infected muscle found in wound shown in *Fig.* 122. Fourteen metallic fragments were removed from this wound by an electro-magnet (see *Fig.* 124). The infection was by hæmolytic streptococci, so that delayed primary suture could not be carried out.



FIG. 124.—Sketch from *x*-ray plate showing fragments of metal in the thigh. In case shown in *Figs.* 122, 123.



FIG. 125.—Showing suture of a wound in thigh. This wound was very septic; it was washed with ether, and packed with 'bipped' gauze for 6 days before suture was attempted. It healed by first intention.

so quickly into the tissues that it may be that no substance applied to the surface of a wound can be expected to have much effect.

The discovery of a serum which would give efficient protection against this type of infection appears to us to be a matter of such importance that we venture to hope a concentrated effort may soon be organized on a sufficiently large scale with the object of solving this problem.

Routine Bacteriological Examination.—Although the preparation of cultures from every wound to be sutured is an undoubted advantage, it is obviously impracticable if suture is to be carried out on a large scale. We believe that careful clinical observation renders routine bacteriological examination unnecessary in the average case. We suggest that in times of pressure, cultures should be taken only from deep and severe wounds, and that the examination should be limited to ascertaining the presence or absence of hæmolytic streptococci. The isolation of other bacteria, and particularly the identification of varieties of anaerobes, does not appear to be necessary in the class of wounds likely to be considered suitable for early closure.

Comparison of Immediate and Delayed Suture.—While it is evident that with careful selection of cases and efficient operation immediate suture may be counted on to meet with a large measure of success, and while immediate suture must be the operation of choice for certain classes of wounds, such as those of the head and chest and those involving joints, yet we incline to the belief that for general use in the average wound delayed suture is safer and more certain in its results.

During periods of active fighting, when cases cannot be retained for at least several days after operation, delayed suture is the only means of early closure at our disposal. This method has the advantage that the presence of virulent infection can be ascertained before the wound is closed, by clinical evidence and microscopical examination. In this way wounds with virulent infection, the majority of which if sutured would be failures, can be excluded from closure till later periods when the infection has been overcome. In the case of severe wounds, and when the operator is in the least doubt as to whether he has succeeded in efficiently removing dead and damaged tissue, delayed suture, in our opinion, should have the preference as a general rule.

In conclusion, we wish to express our thanks to the Medical Research Committee, who have supplied us with a typewriting machine and with literature; to Surgeon-General O'Keefe, who has granted us the facilities and conditions necessary for the work; to Surgeon-General Sir Anthony Bowlby, Colonel Sinclair, and Colonel Gask, consulting surgeons, who have helped us with their advice and interest; and to Lieutenant-Colonel Marriott, D.S.O., officer in command of the unit, who has given us every assistance in his power at all stages of this research. To the Medical Research Committee we are also indebted for placing the services of Sergeant A. K. Maxwell at our disposal. Reproductions of beautiful coloured drawings by this artist illustrate our report.

ACUTE DILATATION OF THE STOMACH.

By WILLIAM DOOLIN, Dublin.

Acute dilatation of the stomach has long been a source of mystery to pathologist and clinician alike. Hilton Fagge, in 1873, published the earliest authoritative account of the condition in English. Prior to that date, isolated cases of a similar condition had been recorded by Rokitanski (1842), Miller and Humby (1853), Bennett (1856), and Wilks (1857). It was recognized and well described by Brinton in his *Lectures on Diseases of the Stomach*, in 1859. In 1899 Albrecht could only find 18 cases recorded in the general literature, and in 1902 Campbell Thomson published an analysis of 44 collected cases. Within the past ten years important references to this question have been published in America by Conner (1907), Laffer (1908), Borchgrevink (1913), and Lee (1916); in France by Delangénière (1909), Lardennois (1910), and Mathieu (1911); and in Germany by Braun and Seidel (1907), Axhausen (1909), v. Haberer (1913) and Linke (1914). English medical and surgical literature during the same period, save for the published cases of Box and Wallace (1911), has been surprisingly reticent on the subject.

The first case of the kind which I met with was in 1910, when house surgeon at St. Vincent's Hospital. The patient was a stout woman in the middle forties, and Professor Alfred Smith was operating for a large myoma uteri. As he was about to close the abdomen, the patient showed signs of respiratory distress, the abdominal walls began to bulge, and the lower border of the stomach appeared in the upper margin of the wound. We noticed at the time that the gastro-epiploic veins and their tributaries were enormously engorged. The condition was immediately recognized, and a stomach tube promptly passed, whereupon a large quantity of gas was brought off, followed by a fair quantity of fluid. This relieved the condition, and the stomach receded into the epigastrium. The tube was left *in situ*, the abdomen closed, and the patient brought back to bed and placed on her right side. There was no recurrence of the dilatation, and the patient made an uneventful recovery.

My second case presented itself under widely different circumstances.

Mrs. J. W., age 19, was admitted to St. Vincent's Hospital late at night on Oct. 10, 1917, as being a case of acute intestinal obstruction. Temperature on admission 97·2°; pulse 148; respirations 24. Patient was very collapsed, with drawn, anxious facies, and heavy rings under the eyes; pupils moderately dilated.

Previous History.—On June 30, 1917, patient gave birth to a premature (7 months) child; labour was normal, but later she developed puerperal sepsis, on which account she was detained for ten weeks in the maternity hospital. She then went home, very weak, and lay for a further three weeks confined to bed.

Present Illness.—On Oct. 8, after "a good dinner" she was suddenly seized with violent epigastric pain; seven or eight hours later she commenced vomiting, which continued incessantly during the night. Her bowels moved naturally once before vomiting set in. The next day a doctor was sent for, who administered an enema, which gave a good result; there was no cessation, however, of pain or vomiting, which continued unabated. The following day vomiting continued, large quantities of yellowish-green fluid, sour to the taste, but of inoffensive odour, coming up incessantly, despite the fact that nothing had passed her lips for thirty-six hours. She was then sent to hospital.

On Admission.—Condition one of extreme exhaustion. The abdomen, which moved freely on respiration, was enormously distended, with a marked prominence below and to the left of the umbilicus. This protrusion was exquisitely tender to the touch, and highly tympanitic. The tympanitic note extended practically to the left nipple line above, out to the flank, and down to a point two finger-breadths above the left Poupart line; it then 'elbowed' sharply upwards to just above and to the right of the umbilicus. Vomiting had ceased shortly after admission, which I took to be of bad omen. During my examination, which lasted nearly half an hour, there were three distinct crises of visible peristalsis, the waves passing from the left above, downwards and to the right: as they passed, the patient moaned with the intensity of the cramping

pain. Succusion splashing was very marked below the umbilicus. Patient remarked she had not passed urine since the previous night; a catheter was passed and 8 ounces of urine were withdrawn. (Urine analysis showed: density 1024; acid; albumin and sugar absent; no casts; no blood-cells; calcium oxalate crystals were present in abundance, and a large proportion of amorphous urates.) Thirst was not complained of.

I thought the patient was *in extremis*. We had the foot of her bed raised on a chair, and she was placed prone on her face, with a large pillow beneath the pelvis. This, she stated, gave her distinct relief from the pain. Nutrient enemata with brandy were administered every three hours during the night, and subcutaneous saline was given under the breasts.

The next morning (Oct. 11) I found the ventral position had given her complete relief from pain. Her facial appearance had improved beyond recognition. Temperature 97·6°; pulse 84; respirations 20. No vomiting during the night. The stomach had receded to about half its size of the previous night. Eighteen ounces of urine were passed in twenty-four hours.

Oct. 12.—Stomach distention quite receded. No pain. No vomiting. Temperature 98°; pulse 78; respirations 20. Patient very hungry; allowed chicken tea, cautiously, in sips. Twenty-two ounces of urine passed in twenty-four hours.

Oct. 30.—After an uneventful recovery, patient went home.

I can ascribe this patient's recovery solely to the use of the prone position. She was well-nigh *in extremis* on admission, so much so that I was afraid to subject her to the physical strain of washing out her stomach. And yet, after twelve hours in the prone position, her condition of extreme collapse was over, her pulse had come down from 148 to 84, and was of good volume, the distressed facies had quite disappeared, she presented a smiling countenance, informed me the pain was gone, and declared herself, notwithstanding the still evident degree of gastric distention, as being quite comfortable.

Had I not had the fortune to have read Borchgrevink's valuable paper previously, and to have recollected his emphatic assertion of the value of treatment by the prone position, I am convinced that the patient would not be alive to-day.

On consulting the usual English text-books, I was very disappointed at the meagre amount of information obtainable concerning this unusual malady and its treatment. The value of the prone position, as borne out by Continental and American authors, does not seem as yet to have obtained adequate recognition in English surgical literature. Thomson and Miles (1915) do not even mention it, but recommend gastrostomy if lavage be unsuccessful. Douglas (*Diseases of the Abdomen*, 1910) recommends lavage, but gives no mention of postural treatment. Paterson (*Diseases of the Stomach*, 1913) advocates lavage and the knee-elbow position. Moynihan (*Abdominal Operations*, 1914) is the sole advocate of the prone position and early lavage. Choyce (*System of Surgery*, 1915) barely refers to postural treatment, recommends lavage, and states that operation is inadvisable. A search through the available literature at my disposal has led me to the conclusion that this malady is by no means infrequent; and that its high mortality may be accounted for by want of early recognition, and by an insufficient understanding of its etiology, leading to injudicious methods of treatment.

The 188 cases which I have succeeded in collecting from available sources may be divided into two large groups:—

1. Where the condition arises as an unexpected and unwelcome sequela to operation.
2. Where the condition arises without any prior operative interference.

Of the 188 cases, 133 (nearly 69 per cent) occurred after operation. This post-operative group is of exceeding interest; 96 of these cases were abdominal operations, of which gynecological operations head the list with 40 cases, operations on the gall-bladder come next with 20, operations on the stomach and duodenum 18, appendicectomy 11, and herniotomy 5. Of the extra-abdominal operations, the kidney gives 7 cases, the thorax 6, the extremities 13, and the face 1.

The group of non-operative cases is well worthy of investigation. Here several sub-groups may be defined. A fairly large number of cases has been reported where the occurrence of the condition was attributed by the observer to intake of excessive quantities of food or drink (dilatio ex ingestis). In another specialized sub-group of 10 cases, the condition was associated with spinal deformity (Wichern, Kelling, Perry and Shaw, Buzzard, Kirch, Kausch, Willett, Neck, Hanssen, Bollag). The condition has also arisen

during the course of acute or long-continued febrile disturbances: pneumonia, for instance, has 4 cases to its credit (Box and Wallace, Campbell Thomson, Herrick, and Leonhardt), as has also typhoid (Brinton (2 cases), Wichern, and Baümler). It has occurred once during the course of phthisis (Neck), diabetes mellitus (Box and Wallace), and sciatica (Baümler). Injury to the abdominal wall has been followed by the development of the condition in 3 cases (Tuffier, Appel, Box and Wallace). Confinement was complicated by acute gastric distention in 4 cases (Campbell Thomson, Laffer, Audebert, and Rice), and Cæsarean section in 2 (Theilhaber and Audebert). Finally, we have an extremely remarkable group where the condition arose suddenly in perfect health, without any explanation whatever; in one case it is recorded that the condition started "in a hearty laugh."

Over 60 per cent of the recorded cases occurred in women. It may arise at any age, but is most frequent between 20 and 40 years. The youngest case was that of a breast-fed child nine months old, found dead two hours after suckling; there was no vomiting, yet at autopsy the stomach was "as large as a football" (Belilios). Cooper has recorded an even more rapid death in a child of eleven months, under very similar circumstances. The oldest case was that of a man, age 86, who was admitted to hospital with an intracapsular fracture of the neck of the femur, and who died within half an hour of taking a glass of milk; the condition was diagnosed at autopsy (Moore).

In the post-operative group, all the operations were carried out under general narcosis, with but two exceptions: one case occurred after spinal analgesia with novocain (Taddei), and one after a herniotomy carried out under a local anæsthetic (Lyle).

ETIOLOGY.

Efforts to explain the genesis of this condition have led to a riot of theories. The very multiplicity of titles* given to the syndrome is in itself an evidence of the numerous hypotheses which have been advanced from time to time in explanation of the origin of this mysterious malady. An 'individual predisposition' has been alleged by some writers who have had the very unpleasant experience of meeting this complication in successive operations upon the same patient; it is obviously an unsatisfactory explanation. Riedel has advanced a theory of serous infiltration of the stomach wall with subsequent dilatation, which, however, has failed to obtain support from other observers. The condition has been ascribed to adrenal incompetency by Arcangeli,† and to a general insufficiency of the chromaffin system by Kuru.† Rokitanski first definitely ascribed the dilatation to compression of the horizontal portion of the duodenum by the root of the mesentery. In this explanation he had the support of subsequent observers such as Kundrat (1891), Albrecht (1899), and Müller (1900). The last writer ingeniously drew attention to one particular class of case not infrequently followed by this distressing complication, viz., where the pelvis or lower abdomen has been occupied for a long period of time by a large ovarian cyst or uterine tumour which, growing up out of the pelvis, has crowded the intestines into the upper abdomen; after removal of the tumour, the coils of gut sink down into the now empty pelvis, and so drag upon the superior mesenteric artery as to compress the duodenum at its crossing.

This theory, which we may call that of 'primary duodenal obstruction,' for long held the field, and even to-day has some supporters. A dilated stomach and a duodenum partly or completely obstructed are two undeniable anatomical facts frequently found on the post-mortem table. Which is the primary phenomenon, however, and which the secondary? It is well-nigh impossible to prove to everyone's satisfaction that a primary occlusion of the duodenum does not, or cannot, cause an acute dilatation of the stomach.

* It has been variously described as "Acute Dilatation of the Stomach," "Gastro-mesenteric Ileus," "Acute Gastroduodenal Atony," "Mesenteriale Darmverschluss," "Traumatische Magenerweiterung," "Paralysie Stomacale Aiguë Post-opératoire," "Gastro-enteroplegia," "Acute Gastrosuccorrhœa," and "Acute Gastric Motor Insufficiency."

† Quoted by Lee.

The theory at first sight is easily acceptable, as we are all familiar with the dilated bowel above the site of constriction in mechanical ileus. Nevertheless, we find on deeper investigation a mass of evidence, direct and indirect, which has led the great majority of recent writers to discard this theory. The first argument that strikes one against Müller's hypothesis is the extreme rarity of such an occurrence after child-birth; of the 188 cases mentioned above, only 4 took place as a postpartum complication. The extreme rapidity with which the stomach may dilate does not point to a mechanical occlusion of the duodenum as being the primary cause; in my first case the stomach swelled up to a truly alarming size within a few minutes, and cases of an almost identical character have been recorded by others (Luckett, Moorehead, Mayoral and Richardson). It seems incredible that a mechanical blockage of the duodenum could break down the resistance of the pylorus and cause an enormous gastric distention in so short a space of time. In high jejunal obstruction, the nearest clinical parallel—as observed by Borchgrevink, Axhausen, Wilms, and others—this great dilatation of the stomach was not found to have taken place. The undoubted recovery of more than half the cases treated by gastric lavage is further evidence against a primary duodenal obstruction. Melchior's argument, that a sufficient degree of traction to cause true occlusion by the mesentery would in all probability cause such interference with the mesenteric circulation itself as to lead directly to thrombosis within the vessels, or necrosis of the intestine, is also very suggestive. Finally, the fact that a noticeable degree of mesenteric compression was found in less than 25 per cent of recorded post-mortem examinations, would lead one to infer that mesenteric compression either is unnecessary for the production of acute dilatation of the stomach, or is a secondary and not a primary phenomenon. To this belief most of the more recent observers are inclined—namely, that the stomach dilates first, and that a duodenal obstruction may be produced secondarily in one of two ways: either by compression of the duodenum by the dilating stomach between the tense abdominal wall and the rigid spinal column (Box and Wallace); or that the stomach, as it dilates, compresses the small intestines, crowding them down into the narrow pelvic cavity, where they are held in place by the superimposed weight of the dilated stomach above; the traction thus exercised on the mesentery causes the compression of the duodenum, which in itself leads to a further dilatation of the stomach, and so the vicious circle is set up. This view had the early support of Lecène and Reynier, the latter of whom says: "L'occlusion duodenale postopératoire ne serait, dans ce cas, qu'une complication des plus graves de la dilatation aiguë de l'estomac."

Practically all recent writers, from 1902 onwards, are in agreement in considering that gastric dilatation is the primary phenomenon. How then are we to account for its occurrence? In 1895, Carrion and Hallon demonstrated that section of the vagus nerves in dogs* led to dilatation of the stomach. In 1900, Stieda cut both vagi in dogs on which he had performed gastro-enterostomy two months previously; this led to an acute dilatation of the stomach, despite a patent anastomotic opening. Brinton, in his *Lectures*, looked on the condition as one of a paralysis of the gastric musculature; that the paralysis is a complete one we cannot accept, in view of the many observations of visible, active peristalsis, and in view of the completeness with which the stomach will recover its tone with early use of the tube. Legueu and Reynier have met with the complication after operations on the kidney; they ascribe its development to a reflex innervation disturbance acting through the solar plexus, and compare it with the appearance of acute retention of urine in the bladder following dilatation of the anus for rectal operations owing to reflex disturbance of the hypogastric plexus. It is improbable that a healthy stomach of normal muscular tone can become the seat of an acute dilatation. A certain quantity of gas is ordinarily present in the stomach; any excess of this is readily got rid of by relaxation of the cardiac orifice and contraction of the stomach. If the relaxation of the

* Hartwell, in 1912, unwittingly repeated their experimental observation on the living subject, when an injury to the vagus nerve, inflicted whilst attempts were being made to check a serious hæmorrhage during thyroidectomy, resulted in an acute dilatation of the stomach with a fatal termination.

cardiac orifice be inhibited, or if contraction of the stomach wall be prevented, we have conditions present which would undoubtedly tend to facilitate dilatation. Kelling's experiments on anæsthetized dogs would certainly seem to show that deep narcosis does prevent relaxation of the cardiac orifice ; the same experiments carried out on non-anæsthetized animals failed to produce dilatation. Payer, in a specially investigated series of 300 cases, found that nearly all his patients, after deep chloroform or ether anæsthesia, demonstrated a certain degree of gastric atony, and this partial atony persisted as a rule for twelve to twenty-four hours after operation. As a large majority of cases of post-operative dilatation of the stomach occurred after prolonged or difficult narcosis, these two independent observations are highly suggestive of a valuable etiological factor, i.e., motor insufficiency.

Motor insufficiency, or lack of tone, however, will not produce acute dilatation ; it is merely a necessary predisposing factor. For the passive condition of atony to pass into the active state of dilatation the stomach must be overloaded with either solid or liquid food, or distended with gas. French writers (Mathieu, Lardennois, and others) lay special stress upon air-swallowing as the immediate etiological factor in post-operative cases. 'Tiquage,' or aerophagia, is frequently noticeable in nervous people, or in those undergoing some phase of mental excitement or anxiety. (My second patient was an habitual aerophagic, and even when warned of the possible risk in view of the gravity of her condition, she still found the greatest difficulty in checking the habit.) Under ether narcosis we frequently observe violent convulsive swallowing efforts on the part of the patient who is resisting the anæsthetic, during which mouthfuls of saliva mixed with air must be carried down into the stomach, and quite possibly act as the starting-point of an acute dilatation on the operating table. The rapidity with which dilatation sets in in some of the reported cases certainly points to gas being the primary distending agent. Diffusion of ether from the circulating blood, an explanation which has been suggested by some observers, is a much less likely explanation of the source of the gas than that of simple air-swallowing.

In other cases, food and drink may easily play a part in the production of the condition, as is clearly to be seen when a person in ordinary health simply eats himself into the condition. The same factor can play an important part in a patient whose gastro-intestinal musculature is in an atonic state either from recent narcosis or prolonged convalescence ; the rapid ingestion of injudicious quantities of food or drink under such circumstances may easily prove the starting-point of an acute dilatation which will gravely imperil the patient's life.

SYMPTOMS.

The most prominent symptoms are vomiting, distention of the abdomen, and collapse. Others are pain in the epigastrium, tenderness over the distended stomach, respiratory embarrassment, visible peristalsis, thirst, and scanty urine. The behaviour of the bowel varies—constipation being the rule, but diarrhœa is mentioned in some of the reports. As a rule, the initial symptom is epigastric pain, due, doubtless, to the rapid gastric distention. If the abdomen be inspected at this stage, the distention in the epigastrium is next noted.

Vomiting sets in early in over 90 per cent of cases, but gives no relief to the pain ; once commenced, it becomes the characteristic feature of the condition, and its frequent occurrence at short intervals has prompted Legueu to the not inapt comparison with the continual emptying of the bladder in ischuria paradoxa. The act of vomiting is effortless ; the fluid seems to well up, frequently accompanied by volumes of gas. The contents of the stomach are watery : at first yellow or green, due to admixture with bile, they become dark brown or black later, owing to admixture with blood. The vomitus may be of sour offensive odour, but is never 'fæculent.' It may be highly irritant. Carmichael records the production of an eczematous condition of the lips and cheeks from this cause in one of his patients ; Reynier has demonstrated the presence of an actual hyperchlorhydria in several of his cases. Free hydrochloric acid is present : lactic acid has been demonstrated in varying quantities. The *bulk* of the vomited material is

astonishing, being far in excess of the amount of fluids ingested. This characteristic of hypersecretion led Morris to give the condition the title 'gastrosuccorrhœa.' Vomiting may cease some hours before death. In one of Legueu's fatal cases, vomiting never occurred at all. Death took place in several cases before vomiting had set in.

Distention develops rapidly ; at first manifest in the epigastric and subcostal areas, it steadily extends downwards past the umbilicus, and may even reach to Poupart's ligament within twenty-four to forty-eight hours. The distended viscus occupies the left side of the abdomen, the right side being very little affected. In my own case this was typically displayed, the fundus portion of the stomach running Poupart-wards like a thick curved tube, then the pyloric portion elbowed sharply upwards again in the middle line to a point slightly above and to the right of the navel. Tenderness is often well marked over this distended area. The area of stomach resonance may extend well up into the thorax, even to the nipple line. Durand records a case where the thoracic tympanitic note led to a diagnosis of pseudo-pneumothorax. Loud splashing sounds are easily elicited within the dilated viscus ; Leonhardt has described a case where such sounds were produced by the cardiac impulse, and occurred synchronously with the cardiac movements. Any doubt as to the seat of the distention will be readily set at rest by the passage of the stomach tube, as fluid, accompanied by gas, will be expelled, sometimes almost explosively, whereupon the abdominal distention will recede, often, however, only to recur a few hours later.

Pain, at first epigastric, and frequently umbilical in site, is usually present, but varies in the degree of its severity. It is exacerbated by the occurrence of visible peristalsis, the patient sometimes screaming aloud with the intensity of the cramping, vice-like pain. It is rarely altogether absent.

Thirst seems to be one of the most constant symptoms, though my patient, curiously enough, never complained spontaneously. Sometimes it is severe beyond description, agonizing in intensity, and unrelieved by salines, enemata, or drinking. In connection with this craving of the body tissues for fluid to replace that lost by vomiting, we frequently find a marked decrease in the quantity of urine excreted, leading on occasions to even a temporary total suppression.

The behaviour of the intestine is variable, and not easy to explain. Absolute constipation has been frequently noticed, flatus and intestinal movements both ceasing ; according to Borchgrevink, their re-establishment is one of the first signs of improvement. A point of special importance has been recorded by four independent observers, viz., that even where a definite degree of mesenteric compression of the duodenum was present, the action of the bowels had not been interfered with ante-mortem (Engström, Walzberg, Zade, Bull, all cited by Borchgrevink.) This directly negatives the suggestion of a paralytic ileus beyond the site of duodenal constriction.

There is no particular rise of temperature or pulse in the early stages ; later, the pulse always increases in rate, without any rise of temperature ; the respiration rate increases in proportion as the pressure beneath the diaphragm embarrasses the heart and lungs.

Hiccough is not a common symptom ; it has been observed by Chavannaz, Campbell Thomson, and Reynier. Cyanosis was noted in three cases (Mayo Robson, Templeton, and Leonhardt). Bloodgood mentions syncope, and vertigo has been observed by Bull and Heine. Dilatation of the pupils is mentioned by Richardson and Farquhar. In Box and Battle's case the raised intra-abdominal tension led to a marked dilatation of the superficial abdominal veins and to œdema of both legs ; notwithstanding the severity of these symptoms, the adoption of postural treatment led to this patient's eventual recovery.

POST-MORTEM APPEARANCES.

The stomach is usually found to be enormously distended ; in one case-report the diaphragm had been elevated by the dilated cardia to the level of the third ribs ; the greater curvature not infrequently is at the level of the symphysis pubis. The distention is largely gaseous, but much free fluid may also be found. The gastric wall is thinned

and stretched out, and the mucosa is often the seat of extravasations, superficial erosions, or fissures, thus affording an explanation of the occasional hæmorrhagic character of the vomitus.

Accounts of the duodenum vary in the different autopsy reports. In a large proportion of the protocols, no mention is made of the duodenum in particular, and we may conclude that in these cases no abnormality was observed. In a smaller proportion, distention is mentioned as being confined to the stomach only, the duodenum being uninvolved in the process. Distention, however, had broken down the pyloric barrier and involved the duodenum in many of the cases. The exact extent of the duodenal distention is of importance in seeking for an explanation of the etiology of this condition. The majority of the earlier authorities found that the duodenum was distended up to the point of its crossing by the fold of mesentery carrying the superior mesenteric blood-vessels; this finding gave origin to the term 'gastromesenteric ileus,' and to the conception that the origin of the condition lay in a mechanical obstruction to the onward passage of the duodenal contents by arterio-mesenteric constriction. In three cases, distention is stated positively as passing *beyond* the point of crossing: in Jessopp's case dilatation of both stomach and duodenum was found, "which passed abruptly to a condition of extreme contraction six inches below the duodenum"; in Hood's case the distention involved the "stomach, duodenum, and first few inches of ileum"; and in 1902 Thomson reported one case in which the distention extended for a distance of eight feet along the small intestine. A true arterio-mesenteric compression was noticed in only about 22 per cent of the post-mortem records; and in only one case (Baümler) did the degree of compression lead to necrosis of the mucosa in the constricted gut.

The small intestine, when mentioned, is usually described as being collapsed, and lying or hanging down into the pelvis, thus leading the observers to the conclusion that the consequent pull or drag upon the mesentery was the directly responsible agent for the compression of the duodenum between the mesenteric vessels and the spinal column; the dilatation of the stomach they thus consider to be secondary to the duodenal occlusion.

Evidence of acute inflammation of the upper portion of the peritoneal cavity is not forthcoming from any of the post-mortem reports I have studied.

PROGNOSIS AND TREATMENT.

An acutely dilated stomach manifests little or no tendency to spontaneous cure; practically all the unrecognized or untreated cases had a fatal issue. Conner's statistics in 1907 showed a mortality of 72 per cent. Laffer's investigations in the following year demonstrated a resultant 63 per cent mortality. Of Borchgrevink's (1913) collected cases, 54 per cent died. Thus, within the past ten years there is an improving prognosis, largely depending upon more widespread recognition of the condition and better methods of treatment. We get a truer perception of the patient's chances if we analyze the mortality of the various methods of treatment adopted:—

1.—Of	31	cases	treated	medically,	29	died,	a mortality	of	93	per cent
2.— „	29	„	„	by operation,	21	„	„		72	„
3.— „	54	„	„	„ lavage,	25	„	„	nearly	50	„
4.— „	30	„	„	„ posture,	2	„	„	„	7	„

Thus, of 114 cases where postural treatment was not carried out, 75 died, giving a combined mortality of 65 per cent; *whereas in the* 30 *cases where postural treatment was adopted, the mortality is reduced with a jump to below* 7 *per cent.*

1. **Medical Treatment.**—Of the first of the above groups, those 'medically' treated, only two survived; in one case recovery was attributed to the administration of hormonal; in the other, recovery took place despite the Fabian inactivity of the medical attendant!

2. **Surgical Treatment.**—Of the cases subjected to operative treatment, five varying surgical procedures were carried out, with the following results :—

i. *Gastrotomy*, with evacuation of the contents of the dilated viscus, was carried out on 6 patients, with 5 deaths.

ii. *Gastrostomy* was employed in 7 cases, with 6 deaths.

iii. *Gastro-enterostomy* was carried out 7 times, with 4 deaths.

iv. *Jejunostomy* was fatal in the only case tried.

v. *Exploratory laparotomy* was performed on 8 occasions, and the dilated stomach, on recognition, emptied either by tube or by manual compression. This procedure was followed by 5 deaths.

Thus, we see that of 31 cases operated upon, only 8 recovered. These are highly discouraging figures.

I. Gastrotomy.

Abbott	1904	*Cit.* Laffer	Death
Appel	1899	*Cit.* Conner	Death
Box and Wallace	1901	*Lancet*, ii, 1259	Death
Farquhar	1911	*Brit. Med. Jour.* i, 675	Recovery
Maylard	1909	*Brit. Med. Jour.* i, 653	Death
Hanssen Löberg	1910	*Cit.* Borchgrevink	Death

II. Gastrostomy.

Hoffmann	1904	*Münch. med. Woch.* 2003	Death
Kehr		*Arch. f. klin. Chir.* lviii, 632	Death
Sommarin	1909	*Cit.* Borchgrevink	Recovery
Watson		*Cit.* Laffer	Death
Wright	1897	*Practitioner*, June, 598	Death
Schilling	1907	*Cit.* Borchgrevink	Death
Brown	1899	*Lancet*, ii, 1017	Death

III. Gastro-enterostomy.

Baillet	1909	*Bull. et Mém. Soc. de Chir.* 191	Death
Robinson	1900	*Cit.* Laffer	Recovery
Brown	1910	*Brit. Med. Jour.* i, 727	Recovery
Körte	1904	*Deut. med. Woch.* 1553	Death
Remond		*Cit.* Laffer	Death
Tschudy	1905	*Cor. Bl. f. schwz. Aerzte*, 80	Death
Torrance	1909	*New York Med. Jour.* lxxxix, 70	Recovery

IV. Jejunostomy.

Bloodgood	1907	*Ann. Surg.* ii, 736	Death

V. Exploratory Laparotomies.

Hochenegg	1891	*Wien. med. Woch.* No. 8	Death
Jessopp	1888	*Lancet*, i, 726	Death
Moorhead	1909	*Jour. Amer. Med. Assoc.* i, 1996	Recovery, by tube
Petit	1900	*Cit.* Conner	Recovery
Templeton	1909	*Clin. Jour.* xxxiv, 302	Recovery
Wahlstrom	1908	*Cit.* Borchgrevink	Death
Bollag	1913	*Cor. Bl. f. schwz. Aerzte*, xliii, 262	Death
Moschcowitz	1912	*Ann. Surg.* lv, 614	Death *

* In spite of subsequent postural treatment and lavage.

3. **Lavage Treatment.**—The next mode of treatment, by the frequent or continuous use of the stomach tube, saved one case out of every two. In the 6 cases, where the condition arose during the course of laparotomy, and where the tube was passed without delay, commencing dilatation was immediately checked, and the threatening complication warded off. The earliest possible use of the tube, therefore, is to be recommended warmly. But once the dilatation has progressed to the extent of producing a secondary mechanical obstruction of the duodenum, the tube fails as an unsupported line of treatment. Over and again the remark occurs in the case histories, "Frequent lavage failed to give relief after twenty-four to thirty-six hours, till the prone position was adopted." It seems a fair deduction that the 25 deaths under the above heading were due to the development of secondary duodenal obstruction, and that many of these, even at the eleventh hour, might have been saved by the use of the abdominal position.

4. **Postural Treatment.**—The adoption of the prone position was first recommended by Schnitzler, of Vienna, in 1895, in a patient who developed acute dilatation of the stomach within a few hours of operation for the cure of hernia. His patient had been vomiting incessantly for two days, and on the third day the prone position was adopted, with almost instantaneous relief.

The method is simplicity itself: the patient is turned over on the abdomen, with a large pillow beneath the pelvis, and the foot of the bed elevated; thereby the fluid which has collected in the lowest portion of the stomach is displaced upwards by gravity; the fluid is then more easily evacuated out of the stomach, and relief is given from the downward drag of the loaded stomach on the intestine: the essential feature of this position is the relief it affords from the mechanical obstruction of the duodenum.

The researches of McLean, Hartwell and Hoguet, and Wilkie, on experimental ileus, have shown the importance of the earliest possible replacement by saline solution of tissue fluid lost by vomiting; thereby the blood-pressure is restored, and the failing circulation re-established by the refilling of the vascular system.

In the early use of the tube, the prone position, and free injections of saline solution, we have a triple line of treatment, which, coupled with early recognition of the condition, should almost rob this hitherto highly fatal malady of its terrors.

* * * * * *

Since the foregoing paper was in type, Mr. W. I. de C. Wheeler has given me the following account of a case of acute dilatation of the stomach which was under his care in February, 1918.

The patient was a young man, admitted to hospital complaining of vague abdominal pains. There had been rapid loss of weight, and vomiting was a prominent symptom. Nevertheless a diagnosis of duodenal ulcer was ultimately made, and the abdomen opened on March 4. A well-marked chronic duodenal ulcer was found. During the exploration of the duodenum the stomach commenced to dilate rapidly and progressively until, in a few minutes, it had the appearance of an over-inflated child's balloon. An attempt was made to anastomose the jejunum to the posterior wall, but it was found utterly impossible to apply a clamp to the stomach. The anterior wall of the stomach was then punctured with a scalpel, and collapsed under slight pressure. The puncture wound was closed, and gastro-enterostomy performed. The stomach was little more than normal in size at the commencement of the operation; dilatation commenced at the moment of palpation of the duodenal ulcer. The mesentery was not subjected to any pull, the veins were not dilated, and no cause can be assigned for the sudden distention of the stomach. The patient made an uneventful recovery.

CONCLUSIONS.

Acute dilatation of the stomach is a clinical entity of more frequent occurrence than the text-books would lead us to believe. It may arise after any abdominal operation, or in the course of a long illness.

Gastric distention is the primary condition ; in about 25 per cent of cases duodenal obstruction supervenes as a secondary phenomenon.

Gastric atony is necessary for its occurrence ; the primary distending agent is most probably gas, due to air-swallowing during narcosis.

Early recognition of the condition and prompt use of the stomach tube will suffice to prevent the secondary duodenal obstruction. Operative intervention for the relief of the fully developed condition is unnecessary, and futile in the majority of cases.

The use of the prone position, and a replacement of tissue fluid depleted by vomiting by intravenous saline solutions, has saved many apparently desperate cases, and should be adopted as a routine procedure.

The etiology of the condition is as yet obscure : further study along the lines of experimental physiology is necessary for its elucidation.

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NOTES ON A CASE OF INTESTINAL OBSTRUCTION: WITH COMMENTS ON BURSTS OF THE INTESTINE.

By RUTHERFORD MORISON, Newcastle-on-Tyne.

The patient, a man, age 66, was admitted to a private hospital, Feb. 21, 1918. I had seen him at home two days earlier and elicited the following history. Ever since the age of twenty he had been troubled at frequent intervals with his 'stomach,' and always had to live with special care. During the 'attacks' he vomited and had some epigastric pain, but never either vomited or passed blood. The 'attacks' were always cured by holidays and freedom from worry, and for the thirteen years preceding the present illness he had been, for him, more than usually well.

The present trouble began in the early months of 1917, and seemed at first to be exactly of the same nature as his previous attacks—epigastric pain and sickness. He was much worried at this time both professionally and at home, and was sleepless.

The digestion trouble seemed gradually to get worse, and about six weeks before my visit an additional pain was added to the digestion one. After dinner at 7.30 p.m. he felt uneasy, and on five occasions had been attacked by paroxysmal pain. After going to bed a feeling of distention, followed by a violent pain, developed. The pain always began at the umbilicus, and sometimes spread to the right side, but never reached as high as the costal margin. The pain was accompanied by loud rumblings of wind and inability to pass flatus. When this could be accomplished, relief came. Otherwise each attack lasted for about two hours, and ended in vomiting the food which he had taken; this and a hypodermic injection of morphia gave relief. The next day after an attack his health was as usual. The last of these attacks occurred a fortnight ago.

Present Condition.—A very thin frail man, who had lost one stone in weight during the past year. On examining his abdomen, I discovered an indefinite but very tender nodule deep in his right iliac fossa, above and internal to the position of the appendix (*Fig.* 126, *a*). Once, momentarily, I felt a spasm of increased peristalsis and heard a rumble. Nothing else was found. The view I took was that he probably had a malignant stricture of the intestine, with threatened obstruction, and he was admitted to a private hospital for further observation, consultation, and examination. *X*-ray examination and a bismuth enema excluded a malignant stricture of the colon. A bismuth meal, followed by *x*-ray examination, showed apparently normal passage of stomach contents through the small intestine into the cæcum. For a few days after this he was encouraged to eat ordinary food, and was examined at frequent intervals. He experienced no discomfort from food, and nothing further being found to confirm my diagnosis, he was sent home with directions to return at once if there was any recurrence of the attacks. Unfortunately he was prejudiced against operation, and though warned by increasing attacks, did not return till March 15, 1918, with active obstruction of small-intestine type, producing severe paroxysmal pains, visible, audible, and palpable peristalsis, inability to pass flatus, and frequent vomiting.

First Operation, March 16, 1918.—His abdomen was opened in the middle line by excision of the umbilicus. Much distended reddened small intestine attempted to escape, but was restrained by a large mop wrung out of hot normal saline. The cæcum was first sought for and found—it was normal. The ileum entering it was of small size and pallid colour. On following this upward, about two feet above the ileocolic junction, a hard nodule, obviously malignant growth, was found, puckering and contracting the gut by extending round it and infiltrating the mesentery. (This nodule was what I had felt

during an early examination.) There was no sign of obstruction above the growth. On following the pallid empty intestine upward about two feet higher a similar growth was encountered, and this was clearly the cause of the obstruction. Above it the intestine was tense, much distended, and reddened, in marked contrast with the flaccid empty pallid condition of the gut below. Remembering a previous experience which had let me and the patient in for a second attack of obstruction soon after the operation, I pulled down and examined the distended intestine above before doing anything further, and about two feet higher than the stricture which was causing the obstruction I found a third, almost occluding the portion of bowel it involved. The mesentery throughout was studded with enlarged glands; there were no growths in the liver or elsewhere in the abdomen.

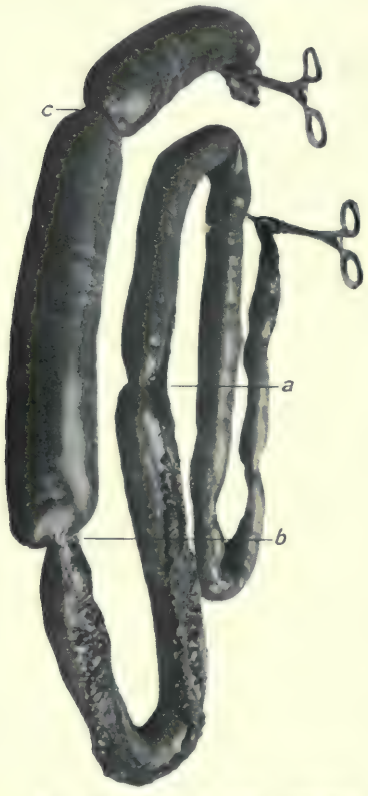


FIG. 126.—Portion of bowel removed, measuring 5 feet 9 inches. It was filled with water from both ends, before being photographed. *a*, Lower stricture; *b*, Stricture causing obstruction found at operation (and now completely impermeable); *c*, Stricture to arrest to site of anastomosis. Note specially the distention between *b* and *c*, where the intestine was almost excluded by the two growths and would soon have burst. Microscopically, the growth was a columnar-celled carcinoma.

A large lateral anastomosis was made between the ileum above the highest stricture and the transverse colon.

After this operation the intestinal symptoms at once disappeared, and during the first twenty-four hours flatus and fæces passed; but the patient was so ill and feeble that, having relieved him, I had almost decided to do nothing further. In the third week his general condition had much improved, but recurring griping pains and renewed audible rumblings made it clear that his intestine had increased difficulty in emptying itself, and knowing what we did, we concluded that the bowel was likely soon to burst below the anastomosis and between the two strictures if nothing further was done.

Second Operation, April 2, 1918.—The abdomen was reopened through the old incision. The ileum was divided below the anastomosis, isolated from its mesentery down to the cæcum, and the whole excised, both upper and lower ends being closed by sutures (*Fig.* 126). Recovery from this second operation was in reality uneventful, and the day following it the patient was entirely relieved. In three weeks he returned home well, and continues to be so still, though he has two or three daily motions.

In a paper on intestinal obstruction published in the *Edinburgh Medical Journal* so long as fourteen years ago (July and August, 1904), I wrote as follows:—

> More than once I have seen the ileum united to the sigmoid flexure in obstruction situated between the cæcum and sigmoid. The result has been distention, gangrene, and perforation of the cæcum, and death from peritonitis a few weeks after the operation. Though I have drawn attention to this self-evident fact before—self-evident if the usual competency of the ileocæcal valve to resist the escape of any of the cæcal contents backwards be remembered—it does not seem, judging by recorded cases, to have met with universal recognition.

In the BRITISH JOURNAL OF SURGERY, 1915, No. 10, in a paper with the title of "Notes on Surgical Diseases of the Colon—a Warning," I related cases illustrating and emphasizing the danger of rupture of the intestine following thoughtless operations for the cure of obstruction due to strictures of the colon.

Hamilton Drummond has done much valuable experimental surgical work during the war, and in connection with the subject of my communication has settled the relative importance of bacteria and tension. He isolated a loop of intestine (cats and hares) by dividing it at either end, and restored the intestinal circulation by an anastomosis. In one series of animals he returned the open loop into the abdomen, into which, of course, its contents and secretion discharged. These animals recovered. In another series he sutured the divided ends of the intestinal loop and returned it to the abdomen securely closed. After making a good recovery from the operation, these animals sooner or later all died or were about to die unless saved by a further operation involving excision of the distended loop. Post-mortem examinations showed that the loop was gangrenous and perforated. In all cases it contained putrid stinking contents, and before it burst presented the same appearance as the rotten-sausage appendix.

G. Grey Turner is, so far as I know, the only other surgeon who has published anything dealing with this problem. In the BRITISH JOURNAL OF SURGERY, 1916, No. 14, in a paper entitled, "The Dangers of Intestinal Occlusion," he relates and illustrates cases bearing upon this subject, and says :—

> As exclusion operations are frequently performed, the matter under consideration may be the cause of unsuccessful results more frequently than is generally supposed. Examinations after death are not often made in the case of patients who die at their own homes, especially when the disclosures of a recent operation apparently render them unnecessary. In text-books the subject is either insufficiently referred to or altogether ignored. These considerations have therefore encouraged me to report my experiences.

Compare these statements with the teaching of one of the greatest surgeons in the most recent text-book (Binnie's *Regional Surgery*, p. 216). This encourages me to reiterate a warning already so often given. The large intestine is in question :—

> *Palliative Operations.*—In a certain number of cases the affected bowel cannot be resected because of the involvement of structures which cannot be removed. In these cases palliative measures become imperative. Ileocolostomy, in which the ileum is joined to some part of the colon beyond the point of obstruction, is frequently indicated.

This is surely sufficient reason for drawing attention again to the dangers of such methods as applied to the colon. The case recorded is an interesting proof that the same principles hold good for the small intestine, and that similar warning may be needful for it; but there are some other points of great practical importance which consideration of the case suggests.

Gangrene of the Hollow Viscera.—Before going further I would like to reiterate my teaching as to how the bursting of the excluded bowel is brought about. It is by the formation, first, of round or oval gangrenous patches, and if these do not perforate, of gangrene of the whole of the involved loop. In current literature gangrene of the hollow viscera is usually attributed to bacterial infection, but I cannot recall a single instance in which this view could reasonably be accepted. All of us thought before the war that gas gangrene at least was primarily due to infection with a special organism. It now seems that even in this variety, vascular defects are the essential primary cause, and bacterial infection secondary. The same is certainly true of the hollow viscera, with very rare exceptions.

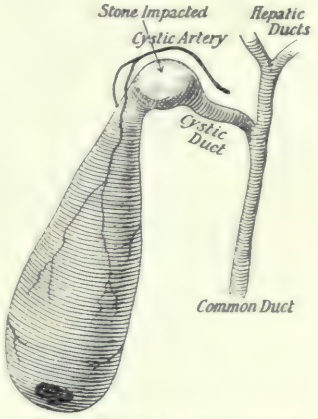


FIG. 127.—Diagram of gall-bladder to illustrate tension gangrene.

A much more common cause than is usually believed, and which I have described as 'tension gangrene,' is not yet sufficiently appreciated. By the kindness of the publishers, Messrs. John Wright & Sons, I am able to reprint illustrations of it which appeared

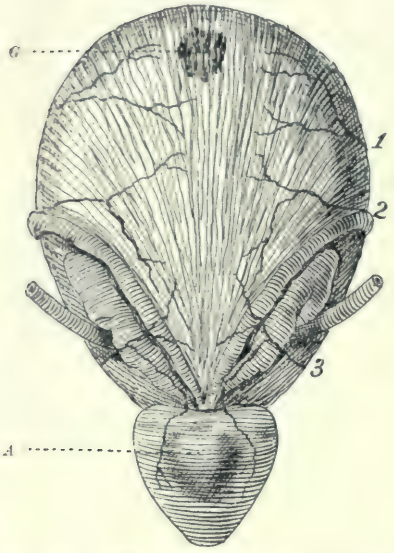


FIG. 128.—Tension gangrene of bladder. *A*, Prostatic abscess; *G*, Gangrene; 1, Superior vesical arteries. 2, Mid-vesical arteries; 3, Inferior vesical arteries. The diagram is from a specimen removed from a young man who had retention of three days' duration from acute gonorrhœal prostatitis and excessive whisky drinking.



FIG. 129.—Diagram of appendix to illustrate tension gangrene.

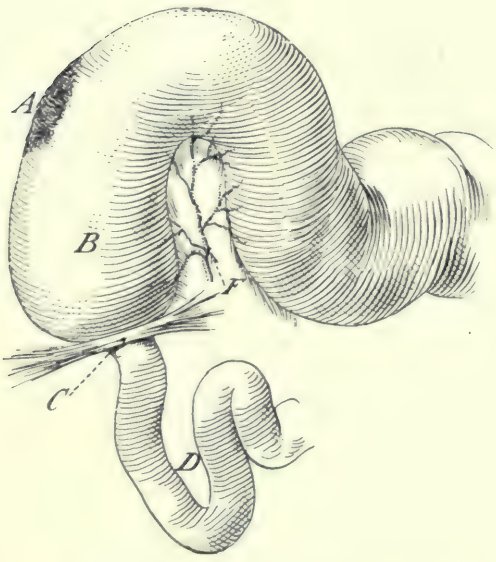


FIG. 130.—Acute intestinal obstruction of two days' duration. *A*, Gangrenous patch; *B*, Small intestine distended; *C*, Constricting band; *D*, Collapsed intestine; *F*, Mesenteric vessels.

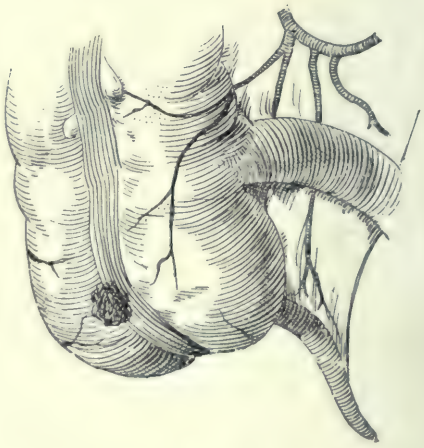


FIG. 131.—Diagram to illustrate tension gangrene in the cæcum.

in my book *An Introduction to Surgery*. They are typical of a form of gangrene frequently seen by anyone on the look out for it, a form which commences as a round or oval patch in a distended hollow viscus at the point furthest from the chief source of its vascular supply (*Figs.* 127, 128, 129, 130, 131).

The case I have related gives an opportunity of describing another cause of gangrene of the hollow viscera which, though not common, may be, and has in my experience proved to be, the cause of disconcerting accidents.

The carcinomatous growth in the case recorded resembles a signet ring, with its seal in the mesenteric border, the ring encircling the gut. In the mesentery there are also enlarged glands. Either the thickened, seal-like induration in the mesentery may obstruct the circulation sufficiently to cause ring gangrene of the gut, or an enlarged gland obstructing one of the larger branches may cause more extensive gangrene of the same. I have had experience of both following simple exploratory operations, and do not doubt that the cardiac failure consequent on operation was the determining cause of thrombosis of vessels interfered with by a growth, either cancerous or sarcomatous.

Another point which consideration of my case suggests refers to the question of palliative operations for cancer, and for tubercle, which so closely resembles it clinically. My own belief, expressed many years ago, is that in the abdomen especially such operations are not sufficiently often performed. In this patient I could entertain no hope of cure; but to give complete relief and restore apparent health, even though for a short time, in an otherwise hopeless and painful condition, is abundant justification of it; and, better still, in a small percentage of cases the results will be more successful than the most sanguine surgeon dare anticipate.

RUPTURE OF THE SMALL INTESTINE INTO THE MESENTERY, THE RESULT OF INDIRECT VIOLENCE OF A MISSILE.

By Major HAMILTON DRUMMOND, R.A.M.C. (T.F.)

Gunshot wounds of the hollow viscera caused by indirect violence have been described by many writers in this war, and Surgeon-General Wallace deals fully with the subject in his Lettsomian Lectures, 1917.[1] In a paper with Capt. J. S. Dunn.[2] we described a condition of laceration of the colon followed by ulceration caused by missiles which passed close to the colon without actually touching the injured gut. We noted how the damage not infrequently extended beyond the bowel wall, resulting in perforation and peritonitis or retroperitoneal cellulitis; such wounds are therefore of so serious a nature as often to prove fatal.

The wounds about to be discussed occur in the small intestine, and were first described by Captain John Fraser.[3] They resemble the colon wounds already mentioned, because the passing projectile brings about an explosive action on the bowel which results in a burst at its weakest point. Before describing the condition further, the following four cases will serve to illustrate the points of importance in this type of wound.

Case 1.—D., age 22, was wounded at 11.30 p.m., and admitted to hospital five hours later. He was much shocked on admission; pulse 120. The abdomen was retracted, rigid, and without any movements. A portion of the transverse colon, with omentum, prolapsed from the exit wound in the mid-axillary line at the level of the tenth rib on the left side; the entry wound was small, and was situated over the fourth lumbar spine.

He was operated upon six hours after being wounded. Operation revealed a bruise wound in the jejunum about three feet from the upper fixed end; a circular hæmorrhage extended round the bowel and up into its mesentery. The leaves of the mesentery were intact, although distended with blood-clot; on squeezing the bowel on each aspect of the bruised area the mesentery was seen to distend with gas, clearly indicating a rupture of the gut between the leaves of the mesentery. The condition was dealt with by freely tearing with dissecting forceps the peritoneum covering the damaged area, and thus exposing the portion of bowel wall uncovered by peritoneum. This allowed of the escape of gas and liquid intestinal contents through a rupture, which showed the typical eversion of mucous membrane usually found. The hole in the gut was closed by a silk purse-string suture, followed by another suture to approximate the torn edges of the mesentery. There were other more severe injuries to the colon and spleen, which accounted for death twenty-six hours after operation.

Post mortem, the bullet track was found to pass forwards and to the left, through the deep muscles of the back, behind the descending colon, and through the posterior margin of the spleen. Then it passed through the diaphragm at its costal attachments, and through the ninth and tenth ribs, portions of which, 1 to 1½ inches in length, were missing.

From a careful study of serial anatomical sections of the body, it would appear that the missile did not come in direct contact with the jejunum, but in its course through the deep muscles of the back injured both colon and jejunum indirectly.

Case 2.—M., age 21, was admitted to hospital six hours after being wounded. As the result of his injuries he died of shock two hours later.

The wound of entry was in the right ilio-costal space in a direct line with the lower angle of the scapula; the exit wound was in the left flank in the anterior axillary line on the same level. The missile had passed below the lower pole of the right kidney, which showed bruising but no laceration; it had entered the body of the third lumbar vertebra, which showed much comminution; and in its course had torn a large hole in the transverse colon near the splenic flexure, and also a loop of the upper jejunum. There were no more ruptures of the small intestine, but the following hæmorrhages occurred in the bowel wall at different points. In the upper jejunum were a number of hæmorrhagic areas. Each bruised

area extended along the bowel for 1 in. to 1½ in. of its length, and involved the whole circumference of the gut. Opposite most of these hæmorrhages the adjacent mesentery showed a triangular-shaped area of extravasated blood, as seen in *Fig.* 133. The intestine between these injuries presented a normal appearance. A second group of similar lesions was present in the lower jejunum, and several single ones occurred in the ileum. None of these injuries, however, showed any rupture of the leaves of the mesentery or of the intestinal wall. The descending colon showed several similar damaged areas.

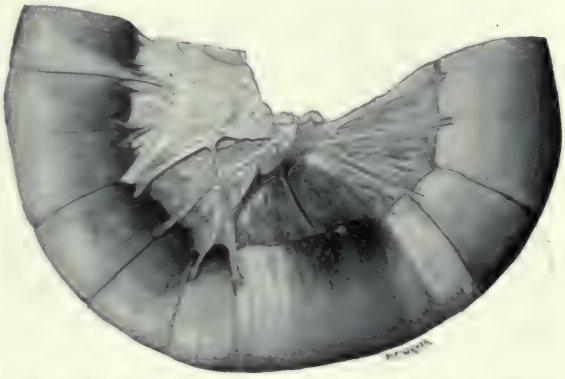


FIG. 132.—Wound of small intestine caused by indirect violence (*Case* 3). Before dissection of mesentery and peritoneal coat of bowel the specimen presented the same appearance as seen in *Fig.* 133. The blood-clot around the ruptured vessel has been removed. Dissection shows thrombosis and rupture of a vessel at a point where it enters the bowel; the muscle coats of the bowel here are lacerated, but show no tear in the mucous membrane.

Case 3.—C., wounded at 2.15 p.m. Aug. 6, 1917, was admitted to hospital 4.50 p.m. on the same day. He died of shock, the result of his wounds, one hour after admission.

In addition to severe limb wounds, he had a compound fracture of the pelvis and abdominal injuries. There was a large entry wound the size of a five-shilling piece above and in front of the great trochanter of the left femur. The missile lay subcutaneously at a point a very short distance behind the anterior superior spine of the left ilium. There was an extensive fracture of the left iliac crest, which could be freely rocked to and fro. The peritoneal cavity contained no blood, and the missile had never perforated it.

The following small-gut injuries were discovered: In the lower jejunum there were two areas of hæmorrhage, each about 1½ inches in length, and extending around the whole circumference of the gut wall under the peritoneum. About one foot of healthy intestine separated the two areas. Both showed extravasation of blood into the mesentery. On dissection, these hæmorrhagic areas showed, after removal of the peritoneum of the bowel and mesentery, a rupture of a large vessel as it entered the bowel wall. The torn vessel was thrombosed, and surrounded by extravasated blood which had found its way along the paths of least resistance towards the larger vessels of the mesentery, and to a lesser extent around the circumference of the bowel wall.



FIG. 133.—Bullet wound of the small intestine (*Case* 4). The leaves of the mesentery are intact. The rupture occurs in the portion of bowel unsupported by peritoneum. At the site of rupture the mesentery is discoloured, from extravasation of blood and intestinal contents between its leaves. Note the hæmorrhagic discoloration around the circumference of the bowel.

The muscle tissue of the bowel wall, at a point where the torn vessels dip through the coats to reach the mucous membrane, showed laceration, but there was no tear of the mucous membrane itself at this point (*Fig.* 132). Examination of the mucous membrane from within showed a thinning of this coat, with hæmorrhagic staining, but no perforation.

Case 4.—F. S., wounded by a shell fragment, was operated upon three hours after his injuries. On admission he suffered from a moderate degree of shock. There was a large single entry wound on the left side of the abdominal wall, midway between the anterior superior spine and the umbilicus, through which about half the small intestine prolapsed. In one place the gut had been completely divided across.

Operation under ether anæsthesia revealed eleven holes in coils of the jejunum and ileum, and in two places the jejunum was found to be divided across, with considerable damage to the mesentery. The damaged area was resected and an anastomosis made. In addition to these injuries, there was a large laceration of the mesentery of the pelvic colon,

and a compound fracture of the ilium on the left side, with much damage to the iliacus muscle.

Examination of the resected portion of small intestine showed four areas with contusion of the mesentery and hæmorrhagic staining around the bowel, similar in appearance to the condition described in *Case* 1. The largest one involved the upper jejunum, with several inches of healthy bowel on each side of it. By making pressure on the gut on each side of the bruised mesentery, gas from the intestine could be squeezed between the mesenteric leaves. The drawing (*Fig.* 133) shows distention of the mesentery between its leaves, due to the extravasation. On examination of the bowel from within, there was a definite circular perforation large enough to admit an ordinary round lead pencil (*Fig.* 134). The vessels in the mesentery leading to the point of rupture in the bowel wall were thrombosed and showed laceration.

There can be no doubt that many perforations of the small bowel due to indirect violence occur in other sites than those just described—namely, into the mesentery—for numerous cases are on record in which, although the peritoneum has not been opened, the gut was ruptured on its lateral or antimesenteric border. Experience has also taught us that when a projectile passes directly through the abdomen, leaving only small entry and exit wounds, sometimes a surprising amount of laceration of small intestine, apparently without any direct wounding of it, may follow. How many of such wounds are caused by direct hits from the projectile and how many by burst-wounds through indirect violence, is an interesting question.



FIG. 134.—Same specimen as *Fig.* 133, laid open to show the rupture into the leaves of the mesentery. Removal of the mesentery showed a typical rosette-like protrusion of mucous membrane, with thrombosis and laceration of the vessels at the point of rupture of the bowel.

Fig. 132 (*Case* 3) serves to illustrate the way in which burst-wounds into the mesentery are caused. The drawing shows an injury to the bowel, caused indirectly by the passing missile, resulting in the rupture of a vessel as it enters the bowel wall from the mesentery. The tear of the vessels in this case must have been due to a sudden impact transmitted from the missile on the wing of the ilium which was fractured ; for no missile could have perforated the peritoneum, since it was not wounded. Moreover, this is the point where rupture of the vessels would be most likely to occur from indirect violence, viz., at the junction of a movable with a more fixed portion—a well-known principle applicable to all injuries. In this instance the blow on the intestine was not severe enough to cause a burst-wound of the gut, for it merely shows a wound of lesser degree.

In *Case* 2, where a rifle bullet passed across the posterior aspect of the abdomen, the explanation offered is that some sudden 'pull' action on the small gut tore the vessels but did not rupture the gut, and multiple hæmorrhages on the bowel and its neighbouring mesentery resulted.

In *Cases* 1 and 4, in addition to tearing of the vessels, rupture of the gut occurred. This was probably brought about by the sudden impact of the passing missile on a gas-filled sac. The weakest point in the small intestine lies between the leaves of the mesentery, for there the bowel is unsupported by peritoneum, and gaps in the muscular coat allow the passage through of the vessels from the mesentery to the mucous and submucous coats make it more vulnerable.

It has already been mentioned that similar burst-wounds occur in the colon, and they are produced by missiles as they pass in close proximity to the intestine in the same way.

It is important to note that the results of the small intestine burst-wounds are much less serious than those in the large intestine, for the two following reasons :—

In the first place, in the case of the small gut the rupture takes place into the mesentery ; if the leaves of the mesentery remain intact, as in *Cases* 1 and 4, they form a

substantial support, and if circumstances are favourable the wound would in all probability progress to a natural cure. The large intestine, as already stated, bursts more frequently between the longitudinal muscles, and often behind the peritoneum, where no great protection is available.

Secondly, the question of infection: in the small bowel there is less organismal activity in the intestinal contents, and consequently ulceration of the mucous membrane has never been noticed in connection with these wounds except in cases examined twenty-four hours after death. In the case of the large intestine the mucous membrane may slough as early as seven hours after the injury.

It is of interest to note that in this type of burst-wound, whether in the large or small bowel, the burst occurs in the same position as that in which pathological sacculi (or, according to present surgical fashion, acquired diverticula) of that particular part of the intestinal tract are ordinarily found. The common site for pathological sacculi in the colon is in the normal sacculi of the gut; whereas the only place where sacculi are found in the small intestine is between the leaves of the mesentery. In both instances the weak musculature at points where blood-vessels perforate the gut wall is largely responsible for this condition. Moreover, it seems reasonable to think, after observation of the pathology of these gunshot wounds, that small-intestine sacculi might well be produced by trauma received many years previously.

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[1] Wallace, Lettsomian Lectures. *Trans. Med. Soc. Lond.*, 1917, xl.
[2] Dunn and Drummond, *Brit. Jour. Surg.*, 1917. v, No. 17.
[3] Fraser and Drummond, *Brit. Med. Jour.*, 1917, March.

SHORT NOTES OF RARE OR OBSCURE CASES.

A CASE OF SUBASTRAGALOID DISLOCATION REDUCED BY OPERATION AFTER SEVEN WEEKS.

By Major S. ALWYN SMITH, D.S.O., R.A.M.C.

Subastragaloid dislocations may be divided into two groups. The true form is that in which the astragalus continues to articulate with the tibia and fibula, but is dislocated from its articulation with the os calcis and scaphoid. In the second variety the astragalus is separated from its articulation with the bones of the leg as well as from that with the os calcis and scaphoid, the so-called complete dislocation.



Fig. 135.—Foot before operation.

The case in question appears to come under the former rather than the latter category, although the astragalus was found to be displaced backwards at the ankle-joint, and was completely dislocated from its articulation with the os calcis and scaphoid.

The patient, E. H., a gunner in the R.F.A., was admitted to the orthopædic department of a war hospital on May 22, 1917. He had been injured on April 17 ; while

he was taking cover in a cellar, a 5·9 shell hit the building and burst through the ground floor, the timbers of which fell on the patient's legs. He was taken to a casualty clearing station, and an unsuccessful attempt was made to reduce the deformity of the right foot under a general anæsthetic. A box splint was applied, and he was sent down the line to England. A second attempt to reduce the deformity was made at a hospital in this country ; but again without success.

Condition on Admission.—There is a Pott's fracture of the left ankle, uniting in good position. The right foot (*Fig.* 135) is markedly adducted at the mid-tarsal joint, and is in a position of extreme varus, the appearance of a well-marked case of club-foot. An adventitious mass of bone is felt in front of the external malleolus. The back of the ankle-joint is markedly thickened, obliterating the contours of the malleolus and the tendo Achillis. Circulation is good ; there is no evidence of gangrene, but the foot is slightly swollen as if there is some slight impediment to venous return. A skiagram (*Fig.* 136) shows the astragalus to be rotated outwards and displaced backwards on the os calcis, and luxated backwards from the lower surface of the tibia. The bone is markedly rotated, and the head of the astragalus is seen to be absolutely dissociated from its normal relationship with the scaphoid.



Fig. 136.—Skiagram of foot before operation.

It was resolved to operate with a view to correcting the deformity by astragalectomy or open reduction.

Operation.—This was performed on June 2, forty-six days after the injury. A 5-in. curved antero-external incision was made in front of the external malleolus, opening into the ankle-joint. The front of the ankle-joint was exposed, and the anterior edge of the lower articular surface of the tibia was dissected free from adhesions. A mass of bone covered with adhesions was found projecting between the external malleolus and the cuboid. On dissection this was found to be the head and neck of the astragalus. The astragalus was thus shown to be displaced backwards and rotated externally forty-five degrees. A large Lambotte lever was placed beneath the tibial aspect of the ankle-joint, and the astragalus forced forwards. The interosseous ligament was found to be ruptured or badly stretched, as the astragalus moved perfectly freely on the os calcis. The astragalus appeared to be well nourished, the cartilage being of normal colour, and the neck of the bone bleeding when the adhesions were freed from it. On this account it was resolved to attempt reposition of the bone instead of resorting to astragalectomy.

A gauze mop was interposed between the gloved hand and the head of the astragalus, and the rotation was corrected by strong digital pressure. A smaller Lambotte lever was now placed behind the scaphoid, the anterior part of the foot was forcibly abducted by this leverage and by the manual efforts of my assistants, the head of the astragalus was forced into place, and when the foot was brought to a right angle and everted it was found that the bone remained in its true anatomical position. The wound was closed

with catgut without drainage, and the foot splinted with a Thomas talipes shoe. The healing was uninterrupted.

Post-operative Treatment.—Daily massage began on June 18, without any passive movements; there was no untoward swelling. Towards the end of July the patient started to move his ankle voluntarily, so passive movements and faradic stimulation were ordered. Voluntary movements were much improved in the beginning of August. On Sept. 1 patient began to walk with light boots, the right one being fitted with an inside iron and outside crook heel and external sole flapper. He walked with crutches for two months, and substituted sticks in November. All movements of the foot and ankle were now free and painless, and the patient could walk for three miles without limp or disability. There was no disturbance of circulation whatsoever. (*Figs.* 137, 138.)



FIG. 137.—Foot after operation.



FIG. 138.—Skiagram of foot after operation.

This case is of interest on account of the nutrition of the astragalus. The major part of its blood-supply comes through the sinus tarsi in connection with the interosseous ligament, and one cannot help feeling that these vessels must have been damaged, on account of the ease with which the bone moved on the os calcis.

My thanks are due to Dr. Bayumi, one of my assistants, who has been in charge of the case, and who has supplied me with the notes.

A CASE OF CONGENITAL ELEVATON OF THE SCAPULA (SPRENGEL'S SHOULDER).

BY CAPTAIN RALPH M. DE MOWBRAY, R.A.M.C. (T.)

IN view of the comparative rarity of the above deformity, the following case may be thought worthy of record.

Pte. M., age 21, was admitted to hospital on Feb. 28, 1917, with a gunshot wound of the right shoulder. During the course of examination it was found that the left shoulder was markedly raised as compared with the other side, and that the movements of the scapula on the chest-wall were limited in all directions. The left arm, moreover, could not be raised vertically above the head.

Palpation at once revealed the presence of a bony process running from the vertebral



FIG. 139.—Skiagram showing abnormal bone articulating with the scapula and vertebral column.

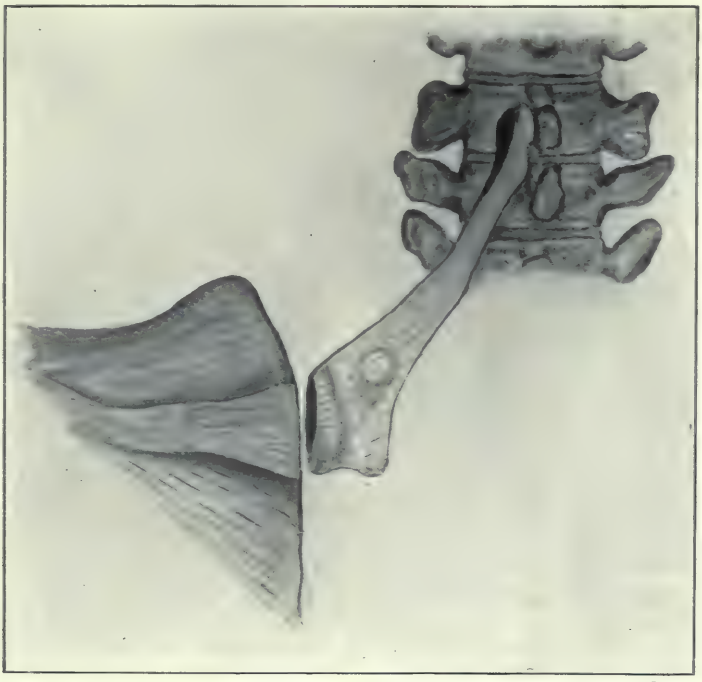


FIG. 140.—Semi-diagrammatic representation of the abnormal bone and its articulations.

border of the scapula, at the level of the spine, upwards and inwards towards the spinous process of the seventh cervical vertebra. *X*-ray examination, kindly undertaken by Captain Garfield Evans, showed a well-formed bone, not unlike a clavicle in general appearance, articulating at its outer extremity with the vertebral border of the scapula (*Fig.* 139). The exact method of attachment of the inner end was, however, difficult to determine, owing to the density of the vertebral bodies.

The patient readily consented to have the bone removed, and this was done on April 6. Superficially the bone was found to be covered by the trapezius muscle, while attached to its deep aspect was a thick muscular belly, apparently a detached portion of the levator anguli scapulæ. As already shown by the *x*-ray plate, a well-formed joint, with an inter-articular fibro-cartilage, was present at the outer attachment of the bone, whilst on its inner extremity were two facets, articulating with the lamina and side of the spinous process of the seventh cervical vertebra (*Fig.* 140). On removal, the bone was found to be 4½ in. in length, the outer end being broad and flat, while the inner tapered almost to a point.

Professor Shattock, who has kindly interested himself in the case, states that the only clue to the morphology of this condition lies in a cartilaginous bar which occupies a somewhat similar position in a special group of fishes (Dipnoi), the attachments in their case being to the top of the scapula and the *occipital* region.

It is satisfactory to note that considerable improvement in the movements of the arm at the shoulder-joint and of the scapula on the chest-wall occurred after the removal of the bone.

CONGENITAL ABNORMALITY OF THE WRIST.

By Captain A. WALDO CONNELLY, A.A.M.C., and Major HOLMES A'COURT, A.A.M.C.

Patient, E. B., is a private in the Australian Imperial Forces, age 17 years 10 months. He enlisted in the Australian Imperial Forces in February, 1916. He did ordinary duty for one month. He was then bugler until his arrival in France in November, 1916. He was 'in the line' on ordinary duty for three months. At this time—that is, in February, 1917—he fell and 'sprained' his right wrist, and states that a swelling appeared on the dorsum. He was then transferred to Divisional Headquarters on account of being under age, and served as batman, although he had difficulty in lifting baggage, etc. The right wrist became more swollen in January, 1918, and he was invalided to hospital.

Family History.—The parents are healthy, and there is no history of any abnormality. The patient has three sisters, age 21, 15, and 12 years respectively; all are said to be normal. There are also two brothers, age 13 and 6 years; patient states that his elder brother has 'weak wrists,' exactly like his own, but he believes the younger brother to be normal.

On Examination.—The patient is a fairly well-made youth, 5 feet 4 inches high, and weighing 9 stone. He states that he has always noticed a "weakness of his wrists, especially the right." Eight years ago his mother took him and his brother to a doctor, on account of "weakness of their wrists, and a hollow over his brother's left wrist." No radiographic examination was made at that time.

At the present time (February, 1918) there is a fluctuating swelling on the dorsal aspect of either wrist, which appears to communicate with the synovial lining of the joint, and can be made to disappear on pressure (*Fig.* 141). It is apparently a diverticulum or hernial protrusion of the synovial membrane, more marked on the right wrist than on the left. Movements at both joints are unrestricted, except that extension of the right wrist produces pain, and the grip of the right hand is weak.

Radiography (*Fig.* 142).—Stereoscopic skiagrams were examined, and show:—

Right Wrist.—There are only six carpal bones present. The trapezoid, os magnum, unciform, and pisiform appear to be definitely recognizable. An imperfectly developed bony

element in relation to the pisiform apparently represents the cuneiform. The small half-moon-shaped bone on the radial side of the carpus is situated in a plane well in front of the trapezoid ; the base of the first metacarpal appears to articulate in front with this bone, and also directly with the radius. If, therefore, this be regarded as representing the trapezium, then the scaphoid and semilunar are entirely absent.



Fig. 141.—Congenital abnormality of the wrist.

Left Wrist.—All the bones are represented, but show many anomalies. There is no styloid process at the radius. Epiphyseal lines have disappeared early.

Ankles.—All the tarsal bones are present in both feet.



Fig. 142.—Skiagram showing abnormal carpal bones. The right- and left-hand figures show the right and left hands respectively

REVIEWS AND NOTICES OF BOOKS.

Handbook of Operative Surgery. By W. I. DE COURCY WHEELER, M.D., F.R.C.S.I., with an Introduction by SIR ALFRED KEOGH. 8vo. Pp. 372, with 226 illustrations. Third edition. 1918. London: Baillière, Tindall & Cox. 12s. 6d. net.

A THIRD edition of this book brought out in these days of difficult publishing witnesses in no uncertain way to the value and usefulness of Mr. Wheeler's work, showing its appreciation by the readers for whom it is written. Everyone who has taught operative surgery will welcome a work from the pen of an authority of such ripe surgical experience as that of the author.

The book is comfortable in size, portable, and printed on good paper. Sixty-nine illustrations have been added to it, not all of which, however, are new or even up-to-date. *Figs.* 196, 220, 224, and 225, for example, appear to illustrate inaccuracy in the artist and an oversight on the part of the author and publishers. Then, pubic hair flourishes in many operations in this era of aseptic surgery: that, at least, is an anachronism. No teacher would instruct a student to open the trachea in a tracheotomy as represented in *Fig.* 56. But these blemishes in the illustrations in no way detract from the excellence of Mr. de Courcy Wheeler's advice and instructions. The book is an excellent one for those "rushing from the medical schools into the service of the Army and the Navy."

That a third edition is called for testifies to its value and usefulness, and to the fact that the object for which the book has been written has been attained; but three points are open to criticism: (1) The inclusion of the civil operations for harelip, cleft-palate, carcinoma, and so on; (2) The exclusion of much military surgery, such as blood-vessels and infections; and (3) The illustrations.

Précis de Radio-diagnostic Technique et Clinique. By DR. JAUGEAS, with Preface by DR. BÉCLÈRE. Large 8vo. Pp. xxviii + 563, with 63 plates and 220 illustrations. 1918. Paris: Masson et Cie. 24 fr.

A PERUSAL of this interesting volume reveals clearly the high value of radio-diagnosis in practical medicine and surgery. It also shows with equal clearness how rapidly and to what an extent this branch of diagnosis has extended its field since the early days of radiography. Perhaps even of greater value is the proof that the radio-diagnostician must now be recognized as one of the more important of the newer consultants. The day has gone when any one who could take an *x*-ray picture was good enough to interpret what he had produced. Dr. Jaugeas, in his title, has clearly placed the radiologist as both a technical man and a clinician, and in the many pages of his work he again and again shows that clinical and technical skill must go hand-in-hand if satisfactory and useful results are to be obtained. The recognition of the radiologist as distinguished from the radiographer will become an assured one when the profession realizes clearly that in radiology a new and most useful field exists for the investment of the best type of brain. The publication of books on the subject as valuable as the present one will go a long way towards furthering the advancement of radio-diagnosis and the specialists who practise in it.

The book is full of clinical material which must be exceedingly useful to the practising surgeon and physician at the present time. The technical side of the work is very completely dealt with in phraesology which reaches a high standard of excellence. The French language seems to lend itself to clear terse descriptions which are readily understood.

The physics of the *x* ray and kindred phenomenon are interestingly described, and a great many experimental data given. This section of the work should prove useful to the

medical man whose knowledge of physics may be elementary. In order to follow the phenomena produced by *x* rays in medicine, both in diagnosis and in therapeutics, a certain knowledge of physics is essential. Dr. Jaugeas supplies this necessary information in a very concise manner.

Instrumentation is thoroughly dealt with, and also various kinds of installations; it is noticeable that the descriptions are almost entirely confined to French types of apparatus, with the exception of the Coolidge tube, which is generously dealt with. Surely there is something good to be obtained from allied countries! One would have liked to see a description of the Baese localizer, which has been so well described by Dr. Bergonié, and so warmly recommended as a reliable instrument.

The book gives a comprehensive *résumé* of the technique necessary for the examination of the whole body, and it is full of useful practical points of value to the radiologist. The technical details are gone into most thoroughly, each part coming in for careful co-ordination. The various methods for obtaining the radiogram—by instantaneous, rapid, and longer exposures—are fully considered.

A noticeable feature is the absence of any attempt to supply exposure tables for the various parts. This is excusable at present, when there is such a diversity of opinion on the matter; but one would have been pleased to observe an indication of a desire on the part of the author for standardization of exposures. Possibly that may come later.

An attempt is made to standardize the positions for the radiography of the various parts of the body. This is a useful section of the work, and will be valuable to the beginner, who so often fails to grasp the essentials of posture in radiography. In this relationship it is worthy of notice that in another section of the work the importance of accurate centering of the *x*-ray tube is made clear, particularly in relation to the localization of foreign bodies. It is equally important, if accurate work is to be looked for, that the *x*-ray bulb should be correctly centered if standard positions are to be obtained; then distortion can be eliminated, and the relative position of parts on the plate ascertained.

Normal radiography is fully described in an interesting section on the subject; this is undoubtedly one of the best parts of the book.

The localization of foreign bodies forms a useful section; in it are described the methods most commonly employed by our allies. Geometrical considerations are fully gone into, and the extraction of the foreign body by the aid of radioscopy is clearly described. The various aids to the operation are illustrated. The compass of Hertz is described at great length, and other forms of a similar type are illustrated.

There is an interesting chapter on fractures, which is very well illustrated by a number of good plates. This will appeal to surgeons. The fallacies of interpretation are clearly demonstrated by drawings and radiograms. The value of radiography in the diagnosis of fractures and the sequelæ of fractures is particularly well shown. The aid it can render in the observation of the repair of bone by examination at intervals and the study of the formation of the bony cicatrix, is particularly pointed out. Numerous interesting points are entered into which all go to show that at the present time radiography is indispensable, and that the greater the clinical and technical skill of the radiologist, the greater will be the value of a collaboration between him and the practical surgeon; it almost points to the need for a surgeon radiologist.

Diseases of bone, including osteomyelitis and tuberculous and syphilitic lesions, are very well described. Tumours of bone also receive adequate description.

The important subject of tuberculous arthritis and osteo-arthritis is described at length; all the principal lesions are dealt with, and a number of them illustrated. This is, perhaps the best manner in which to deal with the subject: it clearly indicates that before long we shall have monographs of the important diseases of bones and joints and other structures, instead of, as at present, compressing all into one large volume.

Lesions of the skull and face are also dealt with. An interesting description is given of deformities of the sella turcica and lesions of the pituitary body, illustrated chiefly by a number of rough drawings; the radiographic illustrations are not of a sufficiently high standard to adequately demonstrate the lesions referred to. Sinus radiography is briefly dealt with. Dental radiography is illustrated by a good plate with four good radiograms.

A long chapter is devoted to lesions of the internal organs, and many good radiograms are reproduced. It is impossible in a review to deal adequately with the sections devoted to the thorax, the abdomen—particularly the alimentary canal—and the renal organs. Suffice it to say that this section is full of radiographic and clinical data of a very high standard. A careful perusal of these interesting pages will well repay the radiologist, the clinician, and the surgeon. The heart and aorta are well described, and the various lesions fully considered. The last section of the book is devoted to the urinary tract: there is a good description of the technique for the exploration of the ureter and renal pelvis by means of collargol and bismuth, a method of great value in the elucidation of obscure symptoms.

The book, taken as a whole, is a first-class production, and serves to show the high

standard of technique which has been evolved by our French *confrères*. Dr. Jaugeas is to be congratulated on the production of a work which amply testifies to his great industry, technical skill, and clinical acumen. It is specially welcome at the present time to English readers as an indication of the value attached to radio-diagnosis in France, and indicates clearly that nothing but good can accrue from an interchange of ideas, technique, and clinical experience between workers in this and allied countries. The time is ripe for a closer *rapprochement* between the radiologists of English-speaking countries and of France.

The Fitting out and Administration of a Naval Hospital Ship. By EDWARD SUTTON, Fleet Surgeon R.N. Pp. 118, with numerous illustrations. 1918. Bristol: John Wright & Sons Ltd. 8s. net.

ONLY one who has had experience of the work on hospital ships can realize the thousand and one difficulties that fall to the lot of the medical officer in command. This small work of a little over one hundred pages serves a most useful purpose, and no officer about to command a hospital ship can afford to be without it.

The opening chapter on the evolution of the hospital ship is most interesting, dealing with the first crude attempts by the French to employ sailing ships as hospitals. The inevitable handicap of then-existing conditions seriously interfered with the arrangements for the comfort and proper treatment of the patients. Refrigerating chambers were unknown, so that fresh food could not be stored, and even the water was only such as could be stored in casks. The noise and bustle of navigating and working the ship, and the necessarily uneven keel of ships propelled by sails, did away with all comfort, and rendered treatment by the medical officer most difficult and unsatisfactory.

Most, if not all, of the hospital ships at present employed have been converted from passenger and cargo ships. The ideal would be to have ships specially designed for hospital purposes. The Japanese have adopted the middle course of designing certain mercantile craft with a view to conversion, if required, into hospital ships. The desiderata are well set forth in the book under review.

Chapter II deals with the Geneva Convention, and gives the rules governing the employment of the hospital ship, all of which it is necessary that the officer in command should be well versed in.

Chapter III indicates certain points to be taken into account when improvising ships for hospital purposes: (*a*) In the selection of a suitable vessel; (*b*) In the location of specific hospital departments.

In the description of the *S.S. Drina*, all details of construction, cabin and cargo space, engines, wards, lounges, boat capacity, accommodation of crew and officers and patients, are given exactly, and no detail is considered too small to enter into. In this way the inexperienced officer who studies this manual can obtain in a few hours what it has hitherto taken a novice months to learn, and that only by bitter experience—in many cases at the expense of the comfort of officers and patients.

A chapter is given on embarkation and disembarkation routine, on information required for the ambulance train, and on book routine and registers. Illustrations of man-handling patients, and diagrams of registration boards, entry and discharge forms, and various other necessary documents, are given towards the end of the book.

The work reflects great credit on the author, who has produced a most useful manual of permanent value.

Poliomyelitis in all its Aspects. By JOHN RUHRÄH, M.D., and E. E. MAYER, M.D. Large 8vo. Pp. 305, with 118 illustrations and 2 plates. 1917. Philadelphia and New York: Lea & Febiger. $3·50.

POLIOMYELITIS, by Ruhräh and Mayer, of the University of Maryland Medical School, is essentially a medical text-book which has strayed into the precincts of a surgical journal. It is a welcome guest, and if therefore immune from criticism, may nevertheless not escape without some trifling eulogy.

It is a most refreshing and lucid account of a fearful epidemic disease. In a delightful historical sequence it presents the patient work of more than a century which has led to the final recognition of the infective nature of the disease, and which leaves the workers hot

on the scent of the mode of spread and the means of prevention. To the surgeon, upon whom the aftermath of terrible deformities falls most heavily, such advances in knowledge are indeed welcome. What surgery can accomplish for such cases, and how best it may be accomplished, is meticulously set forth in a special segment of the book. This—one of the least interesting segments—contains nothing new, and hardly refers to what is the common knowledge of surgeons of experience—that the sum-total of such accomplishment is small. But the public have no illusions upon that point, and their outlook may well be summarized in the following quotation (pp. 96, 97): "Paralysis is the most dominant symptom in a large proportion of cases, and the persistence of paralysis, with the consequent loss of power and function, is what most fixes the attention of the physician and of the layman. A disease may be feared on account of its causing death, but a disease which permits the patient to live in an enfeebled condition is even more dreaded, and its occurrence in a community makes a much deeper impression. The comparative callousness with which the population watches the annual destruction of infants by the diarrhœal diseases is too well known to be commented upon, while 50 cases of poliomyelitis will throw a community of 500,000 into a panicky state of mind." It is not within the power of practical surgery ever to allay such public apprehension; but hope for the public and surgeon alike is stored in the pages of this book, and there is no member of the medical profession of whatever branch who should not feel himself richly repaid by having read it.

Radiography and Radio-Electro-Therapeutics. By Robert Knox, M.D. Vol. II. Pp. 616, with 15 plates and 100 illustrations in the text. London: A. & C. Black Ltd. 15/- net.

The popularity of this book since it appeared in 1915, as one of the Edinburgh Medical Series, has induced the author to deal with the subject of radio-therapeutics rather more fully, and to publish the second edition in two volumes. Vol. II is devoted entirely to radiotherapy, and is the book now under review. It is divided into three portions: (*a*) *X*-ray therapeutics; (*b*) Radium therapy; and (*c*) Radium and *x* rays, the latter part dealing with combined treatment by *x* rays, radium, and other radiations.

From the point of view of the student, one would have liked to have seen technical details described rather more fully; but the subject is dealt with in sufficient detail to make the book an extremely valuable one both for the surgeon and the student who is taking up radiotherapy. The experienced specialist will also find in it much matter of interest. A small section by Mr. Percival Cole on the value of radiation in the plastic surgery of the face and jaws will be found of interest to those engaged in this class of work, and there is no doubt that more attention paid to this subject would be of benefit in many military hospitals.

The book is well and clearly written, and the errors are few and are mostly typographical. It may be confidently recommended to all those interested in this important branch of medical science as the most complete and up-to-date treatise published on this subject at the present time. A word of praise is due to the author for producing a work so well thought out in such times as the present.

Studies in the Anatomy and Surgery of the Nose and Ear. By Adam E. Smith, M.D. New York. 4to. Pp. 157, with 45 plates and figures. 1918. New York: Paul B. Hoeber. $4.00.

"This little volume deals with the anatomy of the nose and ear from a surgical standpoint," as the author states in the preface; but there are also sections dealing with practical points in treatment; thus, while the book is essentially a series of plates illustrating the anatomy of the nasal sinuses and the parts of the temporal bone concerned in mastoid operations from a surgical point of view, the author has touched on the technique of the surgery of the nasal accessory sinuses, and on mastoiditis and its complications.

The opening chapter is devoted to "The importance of nasal breathing." We quote the first six lines: "For several years past much attention has been given to the importance of the removal of superabundant adenoid tissue, which is looked upon as the causative factor for all ills which really are due to defective nasal breathing, without a conception of the truer elation of the various factors involved. I will here dwell particularly on the great importance and marked influence of air pressure upon the internal structures of the nose during normal breathing." The author proceeds to explain that the "air passing through the nasal fossæ from infancy onward exerts marked pressure on all structures within the nose, pushing the lateral walls outward and the floor downward sufficiently to give the space required for the growing capacity of the lungs.

. . . The air normally conducted through the nose and nasopharynx will produce sufficient pressure to support the vessels in the adenoid tissue normally present in the nasopharynx, and hence keeps its growth within bounds." Such false physiological premises naturally lead the author to attribute the clinical features of typical adenoids to mouth breathing: "The absence of air pressure within the nose has permitted the fossæ to remain narrow. If they are sufficiently roomy the mucous membrane covering the turbinals is swollen from non-support. . . . In those in whom there is an abundance of adenoid tissue lining the nasopharyngeal wall, the vessels of this tissue, being unsupported, are continually in a congested state." Not one word is uttered to suggest that infective catarrh is the cause of the turgescence of the nasal mucosa and of the lymphoid hypertrophy which, by causing nasal blockage, compels the child to breathe through its mouth: the whole clinical syndrome of adenoids is explained by the author's curious theory, which we have indicated in his own words, and which, though we are bound to admit its originality, is completely at variance with physiology, physics, or clinical experience as usually accepted.

Chapter II is entitled, "Some suggestions on the treatment of intranasal conditions," and here we find the author recommends what he terms "nasopharyngeal gargling," especially for prolonged use for the cleansing of the nose. It is performed as follows: "After cleansing the teeth and rinsing the mouth, the throat is gargled to free it from food particles and mucus. . . . After taking a long breath, a mouthful of the cleansing solution chosen is taken, the head is thrown back, . . . the palate is relaxed, and the air is blown through the nose. The fluid thus mounts higher and higher into the nose until it is discharged from the anterior nares." While truly an original method, we cannot help stating that this seems an unnecessarily dangerous and even dirty substitute for the more usual spraying of the nasal passages through the anterior nares.

When we turn to the surgical methods for approaching and exposing the nasal sinuses, we cannot avoid the conclusion that the author is ignorant of the more generally accepted technique amongst specialists in this regional surgery of the nose, and that while for anatomical display the routes suggested leave little to be desired, from the clinical standpoint they are sometimes reprehensible. For instance, in the section on "Exposure of the maxillary antrum," p. 89, he says, "if desirable to carry out the flap method as described on *Plates* XXVI and XXVIII, the tissues are incised to form a flap with its base above and including the entire wall of the antrum." True, the author leaves it to the imagination as to what circumstances call for such a procedure, but we are allowed to infer that this is put forward as a regular and legitimate means of exposure of the maxillary antrum, without a word to justify the advocacy of a method which is entirely out of keeping with modern rhinology.

The descriptions of many operations which are to be found in almost every ordinary modern text-book on diseases of the nose are sound, though often too cursory for guidance; it is when the usual routine methods are replaced by the author's own that we find it so difficult to take him seriously.

Much care has been taken in presenting with great accuracy and delicacy a series of plates which are instructive and of anatomical value, and on this aspect of his painstaking work the author, his collaborating artist, and the publishers deserve our thanks and commendation.

Surgery and Diseases of the Mouth and Jaws. By Vilray Papin Blair, A.M., M.D., F.A.C.S. Large 8vo. Pp. xxxi + 733, with 460 illustrations. Third edition. 1918. London: Henry Kimpton. 30s. net.

The author, in his preface to this edition, indicates that the added matter deals largely with the surgery and treatment of war injuries; the bulk of the book has been increased by 100 pages. Such an endeavour is heartily to be welcomed, though its form may not be entirely convenient. This is a necessary disadvantage of incorporating special matter in a book devoted to general lesions. On the other hand, it may be argued that the treatment of these special injuries is so intimately connected with the general principles of surgical procedure that divorce is impossible, or at any rate undesirable. Skilful correlation of a special section devoted to the problems involved would have been arduous; it certainly would have been more satisfactory. The author has been careful to indicate and emphasize principles of treatment based on the clinical experience of sound observers. The policy is admirable, and the more noticeable because the literature of the subject tends to obscure what is fundamental by diffuse elaboration of unessential details. The interdependence of surgeon and dentist is stressed verbally, and confirmed by the scope and treatment of the subjects dealt with.

The least helpful chapters are those that deal with plastic surgery and the surgical restoration of bony defects. Israel's operation is rightly condemned. The restoration of the lower lip by vertical flaps raised from the neck as shown in *Figs* 234, 235 is unsound, and differs essentially

from the method of Dowd, with which it is compared. Morestin himself admits that cartilage grafts do not determine firm continuity when used to fill a bony defect. The space devoted to this operation might well be used to describe other and more effective methods. The same remarks apply to the method of transplanting a bony implant. Imbert & Real have adopted this plan in a series of cases, but the results obtained have not been satisfactory.

Chief among the controversial matters considered are the primary suture of wounds: the use of open-bite splints; and immediate as opposed to gradual reduction of bony deformities. These questions are approached in a manner that is at once accurate and broad-minded. Guidance on these and other matters can only be obtained, however, by assembling scattered references, a disadvantage previously mentioned.

In the section on general anæsthesia, it is pleasing to note that the value of intratracheal insufflation is justly recognized.

There are certain indications of hurried revision. Marten should be spelt Martin, as in the second edition. Wrong figures are occasionally indicated. The defects, however, are relatively trivial. Viewed as a whole, the issue of the third edition is amply justified by the value of the added matter.

Blood-Pressure: its Clinical Applications. By GEORGE W. NORRIS, A.B., M.D., Assistant Professor of Medicine in the University of Pennsylvania. Third edition. Pp. 448, with 110 engravings and 1 coloured plate. 1917. Philadelphia and New York: Lea & Febiger. $3.50.

NEARLY one half of this volume consists of an account of the physiology of the blood-pressure and of the instruments used in estimating and recording it. These sections are of great value both for their clearness and for purposes of reference. The greater part of the remainder is concerned with the blood-pressure in various medical diseases, only thirty-one pages being devoted to surgical matters. The events which follow hæmorrhage are analyzed in some detail; the work of Crile is described in a fair and critical manner, and other views relating to shock, such as those of Yandell Henderson, are summarized. The treatment and prevention of shock are dealt with by taking one by one the various factors in an operation—e.g., manipulation, anæsthesia, etc.—and discussing the relation of these to the question of blood-pressure. Surgical considerations are confined chiefly to those relating to the abdomen or thorax, and there is no direct reference to limb surgery, and especially to operations upon bones or joints, in the production of shock.

A Text-book of First-Aid and Emergency Treatment. By A. C. BURNHAM, M.D., Medical Corps U.S.R. Pp. 307, with 160 figures and 2 plates. 1917. Philadelphia: Lea & Febiger. $2.00.

THIS book, as its title implies, is intended for the instruction of the unqualified student, and it includes a clearly written account of so much anatomy and physiology as is necessary for the intelligent comprehension of the first principles of diagnosis and treatment. Wounds, wound infection, bandaging, fractures and dislocations, burns and bites, shock and heat stroke, suffocation and drowning, various common regional injuries, poisons, some common diseases (varying from toothache to appendicitis), transportation, and the general principles of nursing, are successively and concisely dealt with, aided by well-chosen ilustrations. It is an up-to-date and most useful book.

SHORT NOTES ON BOOKS.

THE University of London Press has published a most valuable series of Military Medical Manuals under the editorship of Sir Alfred Keogh. Unfortunately these are only translations from the French 'Collection Horizon,' and we deplore the fact that it was not possible for the Metropolitan University to produce original English works on the subjects in question. These books have for the most part been reviewed in the original, and therefore it is not necessary to notice them in great detail. The following are among the most important from a surgical point of view:—

The Treatment of Fractures. Vol. I (Fractures involving the joints), pp. 207, figures 97; Vol. II (Fractures involving the long bones), pp. 305, figures 156. By PROF. LERICHE, edited by

F. F. Burghard. These are volumes of great value, especially to English surgeons, because they represent the Lyons school of teaching which has been so little known or understood in this country. Early radical operation, free removal of loose bone, preservation of the periosteum, are the principles maintained throughout. It must be for the thoughtful reader to choose between the dangers and advantages of this teaching, and that of the extreme Liverpool doctrine of the preservation of all fragments.

The Treatment and Repair of Nerve Lesions, pp. 181, figures 62. *Clinical Forms of Nerve Lesions*, pp. 235, figures 78. By Madame Athanassio-Benisty, preface by Prof. Pierre-Marie, edited by Farquhar Buzzard. These two books will probably remain authoritative when many of the other members of this war series are forgotten. Not only is there a careful description of all types of clinical injury, but there are many original observations relating both to the vascular and vasomotor phenomena complicating the results of the injuries of the peripheral nerves, and to the examination of nerve trunks in regard to the position of the various bundles of fibres of special distribution. Unfortunately it is not possible yet to give very extensive figures relating to the results of surgical intervention; but these volumes are a useful guide to diagnosis, treatment, and prognosis.

Artificial Limbs, pp. 156, figures 210. By Prof. A. Broca and Dr. Ducroquet, edited by R. C. Elmslie. A useful description of general principles and the way in which these have been carried out in France. We could wish that the editor had, in addition to his introduction, added a section to each chapter indicating the types of English and American limbs which had been found most useful in his experience.

SIR BENJAMIN COLLINS BRODIE, BART.

1783–1862.

Few gentlemen were attracted to surgery in the days which preceded the introduction of anæsthesia. The training was rough, the physical toil was great, and the mental strain was apt to be overwhelming when a prolonged operation was performed upon a conscious patient. It is no wonder, therefore, that members of the better educated families with a bias towards medicine chose to become physicians rather than surgeons.

Benjamin Brodie was an exception to the rule. He was the fourth child of an Oxford graduate holding the living of Winterslow, in Wiltshire; his mother was the daughter of a banker at Salisbury. From his father he inherited the clear common-sense which characterized him through life; from his mother the business instinct which made him careful in all his money matters without being penurious, for as a member of a large family he learnt early that he must make his way in the world by his own exertions. He was, however, fortunate in his relations, both in law and in medicine. Dr. Denman, the accoucheur, had married his aunt; Sir Richard Croft, equally successful in the same branch of practice, had married a cousin; Dr. Baillie, nephew of William and John Hunter, had married another cousin; Dr. Denman's son, Brodie's cousin, afterwards became Lord Chief Justice, and was well known as one of the advocates at the trial of Queen Caroline; whilst Peter Brodie, his eldest brother, held a high position as a conveyancer.

Brodie was educated privately by his father, and obtained a thorough grounding in Greek, Latin, and mathematics, until he was sent to London in 1801 to study medicine. In the autumn of that year he attended the anatomical lectures given by Abernethy at St. Bartholomew's Hospital and by James Wilson at the Great Windmill Street School of Medicine—for as yet there was no organized medical teaching at the London hospitals, and it was allowable for any student to attend a course on payment of a fee to the lecturer. At the Great Windmill Street School he soon found opportunities to act as demonstrator, and to give occasional lectures in the absence of the recognized teachers. In this way he made his mark, and he maintained his relationship with the School until long after he was well established as a successful surgeon.

In the meantime he did not neglect his social advantages. He was admitted a member of 'The Academical Society,' a small body meeting for the discussion of literary subjects at a house in Bell Yard. Dr. Maton was President, Lord Glenelg and his brother, Bowdler, Dr. Bateman, Sir Henry Ellis, and Lord Chief Justice Cockburn being amongst the members. In 1803 Brodie became a pupil of Everard Home—brother-in-law of John Hunter and surgeon to St. George's Hospital. He studied surgery at this hospital, and from May until November, 1805, he held the office of house surgeon. At the end of this short term of office Everard Home invited him to act as his assistant at operations, and he thus gained an insight into private surgical practice. For the next two years and a half he lived in lodgings in Sackville Street, Piccadilly, without thinking it worth while to put up a doorplate. During this time he revolutionized the clinical teaching at St. George's Hospital, for, living within easy reach of the Hospital, being young, and having little private practice, he was able to devote both time and energy to his hospital duties. He was, besides, fond of teaching, and made it an especial point that the students should make careful notes of their cases, even as he did himself. He also assisted Home in the researches with which he was occupied at the Hunterian collection upon various subjects of comparative anatomy, and he thus became acquainted with Clift, the conservator of

the museum in which the collection was housed at the Royal College of Surgeons in Lincoln's Inn Fields. He was also introduced to Sir Joseph Banks—the President of the Royal Society—who speedily conceived an affection for the well-educated and modest young surgeon, of whose attainments he must have received an excellent account from many sources. Banks invited him to his Sunday evening meetings, and occasionally to dine, and at these gatherings Brodie met all that was best in the social and scientific society of the day. Brodie became assistant surgeon at St. George's Hospital in March, 1808, at the early age of twenty-five, on the nomination of Keate and Home, two of the surgeons, Gunning, the third surgeon, being absent on service in the Peninsular War, and for the next four years Brodie acted as full surgeon, in conjunction with Robert Keate, the other assistant surgeon, although it was not until 1822 that he succeeded officially to the post of full surgeon. On becoming assistant surgeon, Brodie began to deliver lectures upon patients, of the kind now called clinical lectures, in contradistinction to the systematic lectures given by other surgeons and teachers of surgery in London.

In 1809 he took a house in Sackville Street, furnished it with money borrowed from his mother, and began to practise privately. He was elected a Fellow of the Royal Society in 1810, gave the Croonian Lecture *On the Effects Produced by certain Vegetable Poisons*, and was awarded the Copley Medal in 1811, being then only twenty-eight years of age. In the spring of 1812 Mr. Wilson wished to retire from the management of the Great Windmill Street School of Medicine, and proposed that Brodie should acquire the house, the museum, and the goodwill upon payment of £7000. Brodie had neither the money nor the inclination to devote himself entirely to teaching, and the school was afterwards purchased by Sir Charles Bell. In 1816 he married the third daughter of Mr. Serjeant Sellon, she being nineteen and he thirty-three, his income at the time amounting to £1530 from all sources. Three children of this marriage survived their parents. In 1819 he judged that his position had improved sufficiently to justify him in taking a larger house, and he moved accordingly to Savile Row. His work on *Diseases of the Joints* drew him into notice as a surgeon, and from this time onwards his advancement was rapid and uninterrupted, until he rivalled the position which had been attained by Sir Astley Cooper.

In 1819 he succeeded William Lawrence as Professor of Comparative Anatomy and Physiology at the Royal College of Surgeons, holding the post until 1823. In 1821 he was first summoned to Court to attend King George IV, at the time when Sir Astley Cooper removed a sebaceous cyst from the scalp. His attentions were so far appreciated that in 1828, when Sir Astley Cooper was appointed Serjeant Surgeon, Brodie was gazetted as Surgeon to His Majesty's person, and in 1830 he was in constant attendance at Windsor during the King's last illness. In 1832 he was appointed Serjeant Surgeon by King William IV, in succession to Sir Everard Home. Two years later, following a custom dating from the union of the Barbers' Company with the fraternity of Surgeons in 1540, Brodie as Serjeant Surgeon was admitted, on the occasion of the first vacancy, a Member of the Council of the Royal College of Surgeons of England and a member of the Court of Examiners. In 1834 he was raised to the rank of a baronet, and two years later he bought Broome Park in one of the prettiest parts of Surrey. He was elected President of the Royal College of Surgeons of England in 1844, and was chosen the first President of the General Medical Council in 1858. In the same year he achieved the crowning wish of his heart, for he became President of the Royal Society. For some time before his death he suffered from double cataract, for the relief of which he was operated upon by Sir William Bowman. He died at Broome Park on October 21, 1862, full of years and honour.

Brodie was noteworthy in several different aspects. As an educated gentleman, he filled with great distinction the exacting position of President of the Royal Society, and published a series of dialogues to which he gave the name of *Psychological Inquiries*, dealing with the mutual relations of physical organization and the mental faculties.

As a scientific man, it is interesting to note that although he taught anatomy, his main interests, when surgery was based on anatomy, were upon the physiological side.



MEDAL PRESENTED TO SIR BENJAMIN BRODIE BY HIS FORMER PUPILS AT ST. GEORGE'S HOSPITAL.

As a surgeon, his *Pathological and Surgical Observations on the Diseases of the Joints* was the first serious attempt to separate the various conditions which had been previously classed together as 'white swelling.' The grouping was purely clinical, for as yet the microscope had not come into use in surgery. In reading the cases which he records, it is noteworthy that a large number were cases of hysterical joints occurring in young women of the upper classes as a direct outcome of the faulty system of education and hygiene then in vogue; whilst it is to the credit of Brodie that he recognized the value of movement —or, rather, the harmful effects of prolonged rest—on slightly-inflamed joints. In disease of the breast he drew attention to the serocystic sarcoma, which is still called Brodie's tumour. Next to diseases of the joints, he appears to have been most interested in stricture and other surgical diseases of the urinary organs, and by precept and example he recommended lithotrity in preference to lithotomy. Brodie's surgical work was throughout more diagnostic than operative. He performed such operations as were necessary, but it is evident that the manipulative side of surgery did not attract him.

As a medical reformer, Brodie took a leading part in that re-modelling of the surgical side of the profession in England which resulted from the establishment of the new order of Fellows of the Royal College of Surgeons by the Charter of 1843. This charter, for good or for evil, took away all initiative power from the Members and gave it to the Fellows, by whom alone the governing body was elected. Previous to this charter the governing body, or Court of Assistants as it was called, had co-opted its members, who held office for life, a practice which had been continued from the times of the United Company of Barber Surgeons, for at no time had the general body of members exercised any selective right. The charter abolished several obvious abuses, such as the retention of office for life by the examiners and members of Council, and the limitation of the offices of President and Vice-President to the members of the Court of Examiners.

The medal illustrating this article was presented to Sir Benjamin Brodie in 1840 when he retired from office as surgeon to St. George's Hospital. The presentation was made on behalf of his pupils and medical friends as a testimony of their gratitude for the manner in which he had performed all the duties connected with that institution. Lady Brodie always considered the likeness to be particularly happy. There is a bronze replica in the Board Room at St. George's Hospital. The present reproduction is made from a plate in the possession of the Royal Society of Medicine.

BONE GROWTH AND BONE REPAIR.*

By Professor ARTHUR KEITH, F.R.S.

LECTURE III.

RESEARCHES INTO BONE GROWTH AND BONE REPRODUCTION BY OLLIER OF LYONS AND MACEWEN OF GLASGOW.

In almost the selfsame year that Goodsir of Edinburgh was quietly establishing to his own satisfaction that bone corpuscles were the agents which built bones up and took them down, Marie Jean-Pierre Flourens, the permanent secretary of the Academy of Science of Paris, was proving not only to his own satisfaction, but to that of all the world, that Duhamel was right: periosteum was the maternal tissue of bone. When he published his "Recherches sur le Développement des Os et des Dents," in 1842, he was a man of forty-eight, with behind him the most brilliant record of experimental success of any man in Europe. He had that gift which is often given to Frenchmen—a clear incisive engaging style which carries conviction with every sentence. He had repeated and extended Duhamel's observations. Duhamel was right: new bone was deposited on the surface of the bone under and by the periosteum. Hunter was right: absorption of bone was continually taking place; the substance of every living bone was in a constant state of flux. He had destroyed, as Troja had done, the medulla and medullary lining of a long bone, and seen the whole shaft die and the periosteum start into active life and lay down a new shaft. He emphasized the fact that growth in length took place at the epiphyseal lines. People knew of the discoveries of Flourens; those of Goodsir were overlooked.

In 1857 Flourens was ageing rapidly, when a young medical graduate of Monpellier, of the name of Louis Ollier, came to Paris, attracted above all by the great name of Claude Bernard, the genius of experimental research. Ollier was a son of south France; although a graduate of Monpellier, his real University was Lyons; there he had studied under Bonnet, the leading authority of that time on diseases of the joints. In his student days the functions of the periosteum had been debated; Ollier held the opinion that it had no osteogenetic function—in spite of the researches of Duhamel and Flourens. During the short period which he spent in Paris he determined to settle the matter for himself by applying the experimental method of Claude Bernard. He went to work in the laboratory of Chauveau. He selected a young rabbit as the subject of his first experiment. He lifted from the subcutaneous surface of the tibia a tongue-shaped flap of periosteum, leaving it attached by its base. He turned the flap or strip over the deep flexor muscles of the leg so that it formed a kind of annular ligament over them. In six weeks he found that the membrane had become a loop of bone, thick and strong at its base, but tapering towards the tip until it became fibrous. He repeated the experiment in a slightly different form and got the same result; a semi-detached piece of periosteum could form bone. He then proceeded to vary the conditions of his experiment further. He twisted the base of the periosteal flap so that the vessels entering at its base would be compressed. The twisted slip of periosteum produced a beaded string of bony nodules. In a further experiment he raised a process of periosteum, turning it, as before, over the adjoining muscles. Three days later he detached its base from the shaft of the tibia. The detached slip produced bone. He then raised, and at the same time completely detached, a piece

* Three lectures of a course on "The Anatomical and Physiological Principles underlying the Treatment of Injuries to Muscles, Joints, and Bones," delivered at the Royal College of Surgeons, England.

of periosteum, and transplanted it into the subcutaneous tissue of the thigh. He used, for the first time, periosteum as a graft; that graft produced bone. Ollier entered Chauveau's laboratory in Paris a sceptic; when he completed his first series of experiments he was convinced of the osteogenetic properties of periosteum.

We must look closely at Ollier, because he is almost the earliest example we shall meet of a new type of surgeon—one who realized that experimental physiology is, and must be, the basis of all rational operations in surgery. Lister and he were almost contemporaries; Ollier was born in 1830, three years after Lister. Lister gave the first ten years of his career to experimental physiology; so did Ollier. The series of experiments we have just narrated—done when Ollier was in his twenty-eighth year—would have satisfied most young men. Ollier had the qualities of the true investigator: he realized that his experiments had touched only the fringe of the physiology of bone. Hence, when he returned to Lyons in 1859, where he was soon to be called to fill the chair of clinical surgery and serve as surgeon to the Hôtel-Dieu, he continued his investigations year after year until in 1868 he published the results of his experimental and clinical observations in two volumes under the title of "Traité Expérimental et Clinique de la Régénération des Os et de la Production Artificielle du Tissu Osseux." From the time he obtained his first results Ollier had one major object in view—namely, to prove that, after resection of a joint, restoration of the articular ends of the bones was only possible if the operation had been conducted so as to save the periosteum.

When he commenced a second series of experiments in 1858, he devoted his attention more closely to the appearance and structure of the periosteum. Critics had alleged, when he raised the periosteum—which he did by pressing a rugine firmly against the surface of the shaft of the bone—that he also detached fragments of bony matter, and it was these and not the periosteum which gave rise to new bone. He therefore examined with a lens his detached strips of periosteum, and satisfied himself that they were free from visible fragments of bone. He was a proficient microscopist, and studied the minute structure of the periosteum. He defined that membrane as including all the soft tissue which covers the surface of a living bone. When a section of periosteum was studied, as seen on the surface of a growing bone, he could observe a gradual transition of structure from its superficial to its deep surface. As its deepest stratum approached the bone, he observed that it became more cellular in structure, and where it actually mingled with the bone, that these cells were clearly of the bone-forming type—they were osteoblasts. Osteoblasts, he found, were present in the deepest stratum of the periosteum; its deepest layer formed an osteogenetic tissue. It was true, he said, that these osteoblastic cells were sparsely scattered in the deepest stratum of the periosteum of an adult animal, but he also demonstrated that they could be quickly increased in number by irritating a bone by injury.

So he again resorted to his 'flap' experiments. He scraped the deep surface of such tongue-shaped strips of periosteum with his knife, and the soft juicy matter thus collected was transplanted to a living subcutaneous bed; from the matter thus transplanted fine granules of bone were formed. He had thus proved, at least he thought he had, that the deepest stratum of the periosteum had an osteogenetic function. Raising the tongue-shaped flaps from the periosteum of the tibia, he destroyed the deep or osteogenetic layer of one part of it by scraping or by applying a cauterizing fluid, while in the remaining area of the flap the deep layer was left uninjured. On turning such a flap over a muscular bed, he observed that only the intact or uninjured area produced bone. That was, in Ollier's estimation, another proof that the deep stratum of the periosteum produced bone.

Then followed a series of experiments in which he completely detached flaps of periosteum and transplanted them as grafts—heterotopic grafts, he called such slips—to other parts of the body, where they held and produced bone. He found that the success of such grafts depended on many circumstances. There was, in the first place, the occurrence of suppuration. Suppuration, he found, could kill part of a graft and leave another part unaffected; much of Ollier's work is invalidated because he did not know the cause and effects of suppuration. Grafts from young animals took more readily than those from adult animals. Those from the shafts of long bones held better than those from flat bones.

Periosteal grafts of the rabbits had a greater power of reproduction than those of cats. The power varied with the bone ; a periosteal graft from the nasal bone of the cat would hold, while that from the corresponding bone of the rabbit would fail. He showed that the dura mater had a greater osteogenetic power, when transplanted, than the pericranium. All of these results represent real additions to our knowledge of bone life.

Having thus completed his researches on the periosteum, and satisfied himself that it possessed an osteogenetic power to a high degree, Ollier turned his attention to the marrow. He tied the nutrient artery to see if the main arterial supply was necessary for the life and sustenance of the marrow ; he found that ligature made no apparent difference. He failed to raise grafts of bone from transplanted marrow. But he observed that he could increase its osteogenetic power by irritating the bone by injury. To test its osteogenetic power in another way, he introduced a new kind of experiment. He amputated the foot and lower part of the leg of a rabbit, and into the medullary cavity of the tibia thus exposed he introduced an open metallic tube. At the end of a month he found that the tube was filled with ossifying granulation tissue ; that tissue, he concluded, was produced by the marrow, and therefore marrow did possess an osteogenetic power in a low degree.

Having thus tested the powers of periosteum and marrow to form bone, he now passed to bone itself. He found that a piece of bone, detached from periosteum and medulla, could not serve as a graft ; it died, and ultimately became absorbed. It acted amongst living tissues as a foreign body. One would be inclined to suppose that Ollier's experiments on the transplantation of bone fragments had been vitiated by sepsis, did he not go on to describe experiments where such grafts held when they were transplanted with periosteum and marrow still attached to them. In his opinion, pieces of living bone with their periosteum and marrow still intact provided the most perfect form of bone graft ; he supposed that the periosteum served as an intermediary between the bone fragment and the muscle in which it had been implanted. Yet Ollier knew that the shaft of the tibia of a young animal could be completely denuded of periosteum and its marrow entirely removed, and yet live and grow. The results thus obtained confirmed his belief that periosteum was the chief bone-producing tissue.

Ollier made experimental fractures ; the conclusions he drew from them were : (1) The periosteum is the chief agent in forming the callus ; (2) The marrow takes a slight part ; (3) The bone itself takes the least share.

He opened up another new subject when he began to study the effects of experiment on epiphyseal lines of growth. He observed that irritation of the shaft of a bone, by injury, could increase the rate of growth at these lines. Such a result tells one as plainly as can be that there is a mechanism in every bone for correlating the activity of its army of living cells—bone-laying and blood-carrying cells. He discovered that the epiphyseal disc of cartilage could keep up a continuous supply of material for increasing the length of a bone only when it formed an intrinsic part of that bone. When the disc was cut out and transplanted, its growth failed ; it became a disc of bone. It was known before Ollier's time that in every long bone there is an epiphyseal disc of 'maximum growth'—a disc at which the major part of the length of a shaft is produced. The maximal discs for the femur and tibia lie respectively above and below the knee-joint, whereas those for the humerus and radius are placed at the shoulder and at the wrist. Ollier was the first to study experimentally the exact shares taken by the proximal and distal epiphyses in producing the growth of a bone in length.

It is unnecessary here to enter into three other series of experiments carried out by Ollier. He repeated Duhamel's experiments of boring holes in the shafts of growing bones to make certain that growth in length took place only at the epiphyseal lines. In another series he repeated, and extended in great variety, the kind of experiment carried out by Syme—the excision of the shafts of long bones, or parts of a shaft, to discover the share taken by the periosteum in the reproduction of new bone. His conclusion was that the periosteum was the all-important factor ; the surgeon must preserve it when he performed a resection if he would hope for a reproduction of the bony parts which were being excised.

Then there was a third, and in Ollier's opinion the most important, series—those in which he studied the reproduction of joints. His main conclusion one could guess—resections of joints must be performed so that the periosteum covering the excised parts was preserved. He found cartilage to be the most inert, the least endowed with the powers of vitality and reproduction, of all the tissues of the body. On only one occasion did he find a transplanted piece of epiphyseal cartilage produce bone ; he never did see articular cartilage reproduced within a new articulation.

So far we have been following Ollier as an experimental physiologist ; we have time merely to glance at one of his clinical cases—the shoulder-scarred little maid so beautifully portrayed in *Plate VIII* of Vol. II of his treatise. Her name was Louise Gaillard ; she came under Ollier's care in September, 1864, a meagre tuberculous child of five, with suppuration of the shoulder and arm. Ollier removed the upper half of the diseased but living humerus—head, neck, and shaft—by his subperiosteal method. The bone was reproduced. In the following year, 1865, Louise was able to work in a cigarette factory, and a year later, when she was seven, the restored humerus was only 46 mm. shorter than its normal companion. This is one of the classical cases of resection of the humerus. We have noted several others—Charles White's case of 1768, and Syme's case of 1826, and there is another, a resection of the humerus by Hunter. There is also a fifth and yet more famous case which we shall examine in a subsequent part of this lecture.

We shall see presently that Ollier made a grave blunder in the course of his experiments. But when we have made that admission, we have to recognize him as the man who established the evidence on which the principles of bone surgery must be founded. It was he who gave orthopædic surgeons materials for framing a rational charter. The total result of his ten years' investigations was to make him a confirmed Duhamelite—a worshipper of periosteum. We take our leave of Ollier of Lyons with the completion of his great *Treatise* in 1868 ; he was destined to see the commencement of the twentieth century and his labours fully recognized by a new generation of surgeons.

We are now to return to Glasgow. The occasion of our former visit to that city was in 1877, when William Macewen, then aged 29, introduced a new operation for the cure of knock-knee. At the same time he was rectifying the bent tibia of rickety children by the excision of wedge-shaped pieces. In the following year, 1878, a boy, three years of age, was brought to him at the Glasgow Infirmary, emaciated and exhausted from suppuration following acute osteomyelitis of the right humerus. Almost the entire shaft of the bone was dead ; after resection had been performed, there remained in the boy's arm only the extremities of the humerus, the lower being represented merely by the epiphysis, while the upper was made up of the epiphysis and a small part of the shaft. In 1880 the boy was brought back by his parents to have his arm amputated ; it was useless, although the muscles were healthy and could act. No part of the humeral shaft had been reproduced. Making a longitudinal incision deep into the outer aspect of the arm, Macewen planted along the muscular furrow thus opened out a row of tibial grafts. They were pieces obtained by fracturing wedges which had been cut from the bent tibiæ of various boys. Most of these grafts were devoid of periosteum, yet they held and lived. As thus reconstructed the boy's humerus was six inches in length, being made up of three elements : $4\frac{1}{4}$ in. (10·7 cm.) of the shaft, composed of tibial grafts ; the upper part, $1\frac{3}{4}$ in. (4·3 c.m.), derived from the original upper extremity ; and there was also the persistent lower epiphysis. In 1910, when the boy had become a capable workman of 35, he had a useful, well-modelled, if curved, humerus, which measured 11 in., being 3 in. shorter than the normal bone of the left arm. If Ollier's researches had revealed the full truth, then those broken tibial fragments ought to have died and been absorbed ; and yet there can be no doubt they had lived, and given rise to a shaft which had become connected with the persistent upper and lower extremities, and thus become parts of a functional humerus. When he sowed the grafts, Macewen could not have missed noting any ossifications which had survived from the old periosteum. No such ossifications were present. By this operation Macewen demonstrated, for the first time, that fragments of bone may be used as grafts, and that such grafts will live, grow, and reproduce bone. Further, that the

bone reproduced by such grafts can, under tensions and stresses brought to bear on them by the muscles of the part, be moulded to form a real humerus—real in an anatomical as well as in a physiological sense. Macewen's case forms the fifth and greatest of a classical group of famous clinical humeri.

At the time when Macewen was employing bone grafts with great success in Glasgow, Ollier's opinions were in the ascendant in the rest of the world. At first the significance of Macewen's discovery and practice was not generally appreciated, nor was it later. Hence, fully thirty years after he had begun to use fragments of bone as grafts, Macewen, in order to force the truth of his discovery on the attention of surgeons, carried out a series of operations on animals.* He repeated Syme's experiments ; he cut out, subperiosteally, 1¾ in. from a young dog's radius. At the end of four weeks there was still a gap in the bone ; the periosteum had failed to form the missing part of the shaft. He then, in another animal, cut out the whole radius, leaving the periosteum in place ; the periosteum again failed to reproduce bone. He carried out modifications of Ollier's experiments, raising flaps of periosteum from a young dog's radius, folding it round adjacent muscles of the foreleg. Both of his Ollierian flaps of periosteum failed to produce bone. He transplanted grafts of periosteum as Ollier had done, yet failed to succeed in raising bone from them. At first sight it almost looks as if the dogs of Edinburgh and Lyons were provided with a different kind of periosteum to that produced by dogs in Glasgow—in such sharp contrast stand the results of the experimenters of these cities. Yet all three surgeons are equally credible witnesses. There is only one explanation of their discrepant results : Syme and Ollier must have removed the soft tissues which cover bone to a greater depth than did Macewen. The evidence that periosteum, as usually raised by surgeons from the surface of the bones of a growing animal, does produce bone is so positive, so unassailable, that it cannot be rejected because a certain series of experiments gave negative results.

In order to study the effect of periosteum on the growth and life of a bone, Macewen removed this membrane from the radius of a young dog. He found, as Ollier had done, that the bone lived and that its growth was slightly retarded. The shaft lost its smooth contour. On such denuded bone he applied modifications of Duhamel's ring experiment ; the rings became embedded in the shaft of the bone although the periosteum had been cut away

He carried out a series of experiments of a new kind to substantiate his clinical observations—namely, that bone itself could be grafted. He took two dogs, cut an inch out of a radius of each, removed the periosteum from the pieces excised, and broke each of these into fragments. He re-implanted the pieces so that the two dogs exchanged their radial fragments. The grafts held, and complete restoration of the radial shafts resulted. He took two other dogs, and exchanged the right radius of the one for the corresponding bone of the other. In each case the radius was stripped of its periosteum ; yet the transposed bones lived, and became thicker than their untransplanted counterparts. He found that bone shavings, but not bone dust, served well as grafts ; the greater the superficies of a fragment, the better he found it to serve as a graft. The greater the surface of the graft, the greater the area for nourishment and reproduction.

One cannot but admire Macewen's resource in devising experiments. We have seen that Ollier inserted metallic tubes within the medullary cavity to test the power of marrow to reproduce bone. Macewen used glass tubes, not to test the growth of marrow, but to exclude the periosteum from taking any part in filling up the gap resulting from the excision of a segment from the shaft of a bone. Having cut out a segment, he inserted in its place an open glass tube, so that the open ends of the tube faced the cut ends of the shaft. The tube became filled from the shaft with growing tissue which ossified. The new bone thus formed came from the shaft ; it could not have come from the periosteum. He conceived it possible that an absorbable ferrule placed round the adjacent ends of a broken

* *The Growth of Bone ; Observations on Osteogenesis*, Glasgow, 1912.

bone might accelerate union by serving to confine the repairing exudate. Such a tube took the place of the periosteum, which Macewen regarded as a 'limiting' membrane.

We do not suppose that the briefly-narrated researches of John Goodsir were known to Sir William Macewen when he carried out these experiments; yet his definition of the function of the periosteum, as a membrane to limit the excursions of the osteoblast to prevent bone-building cells from invading surrounding tissues, is an exact replica of John Goodsir's conception. The dissecting-room and laboratory observations which Goodsir made in the fifth decade of the nineteenth century led him to formulate exactly the same conception of bone growth as Macewen arrived at seventy years later from a life of active clinical and experimental observation. Macewen, however, has much better evidence of the limiting function of the periosteum to lay before us than had Goodsir. He cites evidence from a case where osteoblasts had been carried within an aneurysmal sac and set up ossification in the fibrinous walls; he describes cases where the exudate from fractured surfaces has been disseminated by massage into the surrounding ruptured muscles, where it formed a mass of ossific tissue; he cites instances of fractures where the periosteum has been much torn, thus permitting osteoblasts to escape into the surrounding tissues and form bone. He alludes to cases where the periosteum has fallen between the broken ends of bones and prevented union. He thus gives a logical explanation of Hunter's observation that the periosteum or tissues which surround a broken or diseased bone may take on an 'ossific disposition.'

There is another series of Macewen's experiments to which we must allude before we leave his work. We have seen that Ollier studied the epiphyseal discs of growth. Macewen rightly protests that such discs have nothing to do with epiphyses; the epiphysis has its own peculiar independent nature. The growth disc is part of the shaft—of the diaphysis—and therefore ought to be called the diaphyseal disc, or shaft-disc. It is solely concerned, as he has demonstrated, with the growth of the shaft. He removed the shaft of the radius from a young dog, leaving merely the epiphyses and diaphyseal discs. In six weeks the shaft was reproduced, not from the periosteum, but from the diaphyseal discs. The point of meeting between the parts of the shaft produced from the proximal and distal discs could still be seen in the restored radius. To make certain his interpretation was right, he removed 2½ in. from the shaft of a growing dog's radius, and covered each cut end with a metal cap. In seven weeks the caps had met. He removed the distal third of the shaft of a radius, including the epiphysis; he found, as Ollier had done, that the part excised was reproduced with an epiphysis, but there was a degree of shortening. Ollier believed reproduction in such cases of excision was done from the periosteum; Macewen shows it is done by growth of the shaft in length. The idea that compensatory growth at the diaphyseal discs may be utilized by surgeons to make good an extensive gap in the shaft of a bone is a discovery we owe to Macewen.

Macewen's work brings us down to the position of our knowledge regarding the growth and reproduction of bone at the present day. We have seen Duhamelites and Hallerites come into existence in the eighteenth century; we have seen them in the persons of Syme and Goodsir in the nineteenth century; and here we are in the twentieth century still with the same two sects—those who regard periosteum as the chief osteogenetic element of the human skeleton, and those who regard bone itself as that element. Where is the truth? As in most cases of this kind, there is truth on both sides, but the greater share is on Macewen's. My interpretation of his work is this. Orthopædic surgeons lay it down as a basal principle that a deformity, to be remedied, has first to be over-corrected. That is what I think Macewen has done. His has been a great practical service; he has given bone its rightful place among the living tissues of the body—a tissue which has the power to reproduce itself. But in raising bone to its proper biological and surgical status, he has been less than just to periosteum. Periosteum can reproduce bone, for no one has yet made a microscopical examination of the periosteum of growing or of inflamed bone and failed to find in it those very elements which Macewen admits to be the creators of bone—osteoblasts. From an anatomical, and I think also from a surgical, point of view, the osteogenetic power of the deepest stratum of the periosteum cannot be denied.

WEIGHT EXTENSION IN THE TREATMENT OF WAR FRACTURES.

By Lieutenant W. H. OGILVIE, R.A.M.C. (T.C.)

During two and a half years' work at the Urgency Cases Hospital, I was enabled, through the kindness of my chief, Mr. Cairns Forsyth, to see a great deal of the methods and apparatus used in the treatment of war fractures in the French army, both at the hospitals round us in the 'zones des armées,' and at the Paris base hospitals. I had also the opportunity, while on leave, of seeing something of British methods. During the same period the care of several thousand patients, of whom the majority were cases of war fractures or injuries of joints, enabled me to compare the value of the different methods by the only real test, that of personal experience, and to evolve a line of treatment which gave the most satisfactory results. Such a system was in no part original, but compounded from the ideas of a great many people—and chiefly from those of Dr. Blake, of New York City, whose wards I was privileged to visit at Neuilly in 1915 and at Ris Orangis in 1916; yet it was the logical outcome of a few simple principles, chiefly those of suspension and weight extension, to which all experience seems to point, and yet which are by no means universally admitted.

On transferring to the R.A.M.C. in October, 1917, I found that the conclusions to which I had been led differed in so many points from British practice as I saw it, that I considered it worth while to set down in writing for my friends on the surgical division an account of the methods we had been using and of the principles underlying them. While any such detailed account of methods and apparatus is of small practical value unless backed by results, a consideration from an outside point of view of the general principles involved in the treatment of fractures is perhaps of enough interest to those working at this subject to warrant its publication.

The fractures seen in war differ from those occurring in civil life in respect of their causal agent, the nature of the injury inflicted, and the methods of treatment applicable for their repair.

Causal Agent.—War fractures are caused by a small heavy projectile travelling at an enormous velocity, which as a rule penetrates the whole limb, and fractures the bone by actually passing through its substance. Civil fractures are usually caused by some considerable force acting with much less suddenness upon the limb as a whole, and breaking the bone by force transmitted through the soft tissues. The practical results of this difference in the manner of infliction of the fracture are as follows:—

Nature of Injury.—1. Civil fractures are often transverse or oblique. Where there is comminution, this is not usually excessive; the bony fragments are moderate in number and of appreciable size. Moreover, the fragments retain part at any rate of their attachments and blood supply, and are not far displaced from their normal position. It would be theoretically possible, by dovetailing the pieces together, to restore the original form of the bone. War fractures, on the other hand, are usually comminuted. The comminution is perhaps more local than that caused by indirect violence, but is far more complete. The fragments are of all sizes, down to mere bone dust. Many of them have lost their viability owing to direct injury, or have been torn away from their blood supply; they have often been transported far from their normal position, or even blown right out of the limb. The important thing is that in the former class it is often possible by traction and manipulation to 'set' the fracture, so that there is some tendency for the fragments to remain in position if suitably supported. In war fractures there is no question of restoring the original shape of the bone, and the broken ends, even if brought into correct position, have no such tendency to interlock.

2. A similar condition is found in the case of the natural splints of an injured bone—the muscles taking origin from it, inserted into it, or lying along it. In a war wound, those lying in the path of the missile have been completely destroyed, and when the fracture has been put into position, their support is no longer available to keep it there.

3. Civil fractures are often simple. When compound, infection is not certain, and may be of a very mild order. But every war wound must be treated as potentially the seat of a virulent infection, for the high-speed projectile leaves a track lined with killed tissues on which any bacteria present can flourish. Again, in a war fracture, the wound necessarily communicates with the fracture, and infected material has passed through the bone itself. In civil practice an infected wound may coincide with an uninfected fracture. Therefore, while in an accidental fracture the claims of dressing may often give way to those of splinting, in a war fracture the wound is a question of life, and the treatment of the fracture a question of secondary urgency. Thus, no apparatus is permissible which does not allow free inspection of the wound and ready access for dressing.

Treatment.—It follows that a method suitable for the treatment of a war fracture must satisfy the following requirements. Fixation must be continuous until union has commenced. It must at the same time leave the wound (and therefore necessarily the seat of fracture) accessible for frequent and extensive dressings, and also allow ready inspection of the limb on either side of the injury. It must be possible for this dressing and inspection to be carried out without interfering at all with the fixation of the fracture.

All forms of splint moulded to the limb, or retaining position by pressing on the bone at or near the seat of fracture, are therefore out of court. Only two methods satisfy the requirements: (1) Direct fixation of the fractured bone itself by plates, wires, or pegs; (2) Continuous traction on the fractured segment from points outside the injured area. The severity of the infection found in the wounds, and the invariable implication of the bone itself in this infection, forbid the first method. Some form of traction, then, is the only one which will at the same time allow continuous fixation and ready accessibility.

The traction may be effected in two ways: (1) By *counter-extension* against some part of the skin surface, this surface being usually at the insertion of the limb into the trunk; and (2) By *extension with weights* running over pulleys, using the mass of the body as the force against which the extension is made.

1. COUNTER-EXTENSION.

This principle is the one by far the most commonly employed at present, and is exemplified in the Thomas knee and arm splints, and in the Robert Jones humerus splint. It has, however, the following serious disadvantages:—

1. The natural place from which to take counter-pressure is at the junction of the limb with the trunk. This situation has many drawbacks, none the less real because they can to a large extent be overcome by care and ingenuity: (*a*) There is a danger of pressure on the main vessels and nerves (this is greater in the case of the axilla than of the groin); (*b*) Where there is no such serious pressure as this, there is none the less a liability to congestion in the limb distal to the ring, and during the acute stage of infection passive congestion is an unmixed evil; (*c*) Perspiration in the axilla, and excreta in the case of the perineum, make it difficult to keep the skin in good condition.

2. It is very hard to make any skin surface take continuously the pressure that is required to make *certain* of correct length, because of the liability of the skin area to slough. For example, in the case of a fractured femur, a pull of 20 lb. is often required initially; at the lowest rate one of 15 lb. must be exerted for the first three weeks. The skin of the buttock and perineum cannot stand anything like this amount of pressure continuously.

3. The ring is always a hindrance to proper inspection. In the case of a high fracture it also interferes with adequate attention to the wound.

4. The amount of extension applied is guessed, not known. This is unscientific.

5. Traction is never steady; even if its average strength is correct, it will at one

time be excessive, at another insufficient; both extremes are harmful. In the case of the Thomas knee-splint applied to the lower limb, a very slight amount of flexion or of abduction will lengthen the distance between the two fixed points by half an inch, and largely nullify the extension.

The exact control of the extending force is of more importance than might appear at first sight. It is obvious that an insufficient pull will never overcome shortening; but an excessive pull, though a much lesser evil, is still to be avoided, because (*a*) any traction in excess of requirements is an unnecessary strain upon ligaments, and (*b*) an extension glued to the skin will give way in the third or fourth week, sometimes lacerating the skin considerably and making further treatment difficult. Such an extension will only take a certain amount of pull at any time, and as the limb to which it is attached shrinks and the epidermal cells are shed, its adhesion becomes less. However, as the muscles weaken and consolidation commences, a less pull is required. If the extending force is limited to that actually necessary, and reduced as circumstances permit, the extension can be made to last the whole of the time required to get a satisfactory result. With a haphazard pull it cannot.

6. The pull exerted depends entirely upon correct application and continual adjustment. There is no automatic compensation, but any gliding of the extension, slipping of knots, elongation of bands, compression of pads, or wasting of the limb, means that the traction has been impaired, only to be restored when the apparatus is readjusted.

2. WEIGHT EXTENSION.

As opposed to the above method, the pull exerted by weight extension is exactly calculated, variable at will, and, being automatically adjusted, it remains of the required strength at all times and under all conditions.

It may be urged against weight extension that it is essentially a hospital method. True. But fractures are hospital cases, and under modern conditions can easily be brought within twenty-four to forty-eight hours to a hospital where treatment can be efficiently carried out. Counter-extension is amply good enough for the temporary fixation of a fracture during transport, but that is no reason why it should not be replaced by more scientific methods during the remainder of the treatment.

The chief drawbacks to the Thomas as a weight-extension splint, are the complete ring above and the closed end below. The complete ring is not being used for counter-pressure, and remains, like the pineal body and the appendix, a developmental indication of a different function in a former existence.

The fracture splint which I first saw at Blake's hospital in July, 1915, and whose use in cases of wounds of the knee-joint I described in 1916 and 1917,* seems to me to be the nearest approach to the ideal extension splint for fractures of the lower limb. It has the following advantages over a Thomas:—

1. *In manufacture.* It is made out of one piece of iron, and anybody can make it who has an elementary knowledge of the use of tools. I had mine made by a blacksmith at Bar-le-Duc at a trifling cost.

2. *In transport.* One dozen Blake splints can be put in the space occupied by four Thomas splints.

3. *In uniformity.* One size only is required, that for an average thigh. Not only does this simplify manufacture, supply, and distribution enormously, but a good fit is certain instead of being extremely rare. It is easy to make the upper end wider or narrower to fit any limb. Against this advantage must be set the fact that a different splint is required for the right or left limb.

4. *In ease of application.* The slings, padding, and foot-piece—if used—can all be fixed up beforehand, and the limb merely laid in the splint and fixed instantly. It is much easier to get the correct support for the limb in this way.

* *Guy's Hosp. Gaz.*, Oct. 21, 1916; *Lyon Chirurg.*, Jan. and Feb., 1917; *Brit. Med. Jour.*, Sept. 5, 1917.

5. *Fixation for travelling* is as good as in a Thomas, and is more rapidly effected.

6. *It satisfies all requirements in itself*, and can be used as: (*a*) A simple counter-extension splint, Thomas type; (*b*) Inverted, as a straight Hodgen; (*c*) As a trough splint with fixed foot-piece; (*d*) As extension splint, with sliding foot-piece, Sinclair type; (*e*) As screw-extension splint, Wallace-Maybury type; (*f*) As splint for suspension of foot by metatarsus.

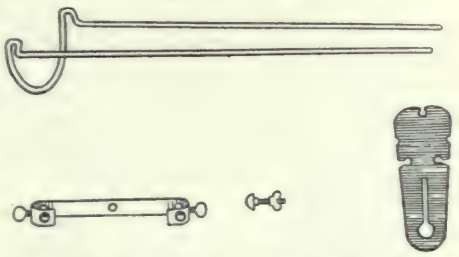


FIG. 143.—Blake splint, cross-piece, and foot-piece.

7. *On reaching hospital*, it is ideally suited for slinging and weight-extension. Cords of the required length are kept ready, with hooks to fit on to the parts of the splint designed for this purpose, and each case is fixed up without any measuring or tying of knots.

8. *During the course of treatment*, readjustment of slings or alterations in the foot-piece can be effected with the minimum of disturbance.

As used by us at Revigny, the Blake splint consists of the following parts (*Fig.* 143):—

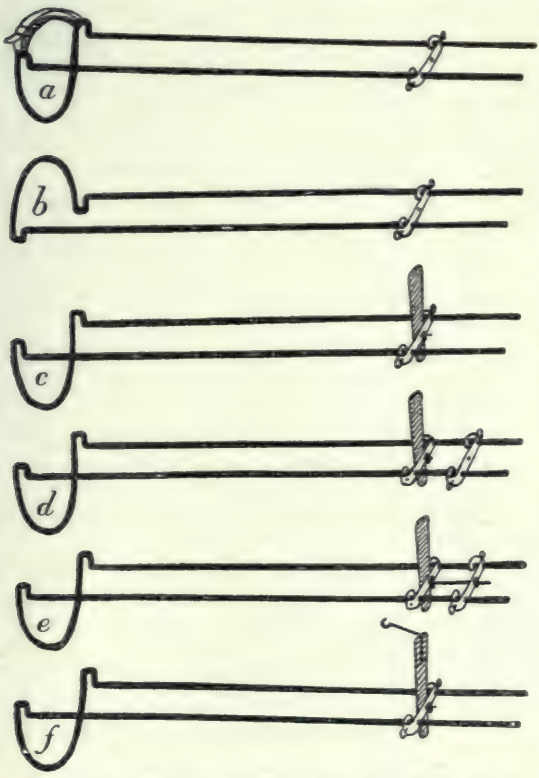


FIG. 144.—Various methods of using the splint: (*a*) As Thomas splint; (*b*) As straight Hodgen (inverted); (*c*) As trough splint with fixed foot-piece; (*d*) Ditto with sliding foot-piece; (*e*) Ditto with screw traction foot-piece; (*f*) As splint for suspension of metatarsus.

1. The splint itself. This is made of bar iron 9 mm. in diameter, and may be described as consisting of two parallel bars united at their upper end by a U-piece set at an angle. The inner limb is 105 cm. in length, the outer limb 10 cm. longer. Where the U joins each side bar, there is a small inverted bend 1·5 cm. wide. To these bends are attached webbing straps during transport, and the suspension cords during hospital treatment. These bends are turned outwards, so that the width between the upper ends of the side bars is 4 cm. greater than the width between the bends at their junction with the U. The U-piece is covered with flannel bandage covered with thin rubber, for which purpose a portion of the inner tube of a pedal bicycle tyre serves excellently. This padding is comfortable, clean, washable, and has no seams.

2. The cross-piece, which can be rigidly fixed to the side bars by its screws; or it can slide upon them, in which case a second fixed cross-piece is added to give the bars stability. Through the central hole passes a bolt with a wing-nut. To the lateral fixing-screws the lower suspension cords are attached.

3. The foot-piece, which is made of iron 2 mm. thick.

The various methods in which these three pieces of apparatus may be used in the treatment of fractures of the lower limb will be seen from *Fig.* 144.

Having reached the conclusion that weight extension combined with suspension is

not only theoretically the soundest, but is practically the best, method of treatment in war fractures, it remains to be seen what is the most satisfactory way in which these principles can be applied. We require an apparatus which will allow us to suspend any fracture, whether of the upper or lower limb, in any desired position, and at the same time to take a pull in the line of the fractured bone. Such an apparatus must first of all be efficient ; but granted that the above essentials are fulfilled, the simplest and cheapest apparatus is the best.

Where beds with rails at the head and foot are in use, it is very hard to improve on the simple frame originally introduced by Blake at the beginning of the war, and used continuously during the last three years at his own and many other French hospitals. A diagram (*Fig.* 145) will explain its construction more readily than a verbal description.

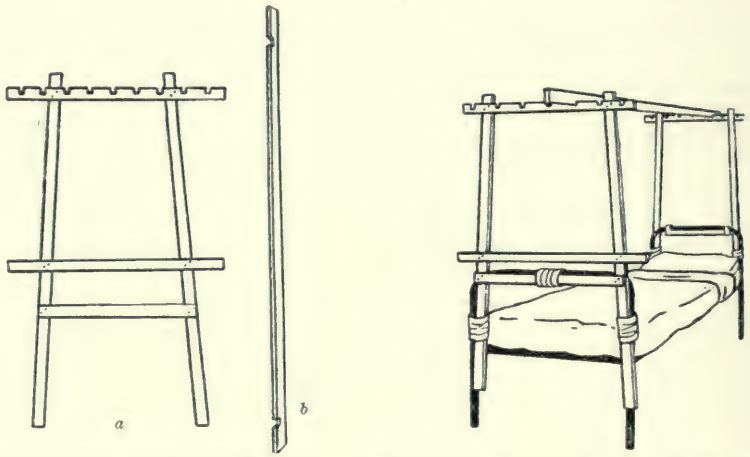


FIG. 145.—Blake's suspension-extension frame. (*a*) End member, (*b*) Overhead bar, (*c*) Frame erected.

It is light, strong, simple, and extremely cheap to make. The ones we had made at Revigny cost 8 francs each. It can be erected in a few minutes, and when erected becomes an integral part of the bed, to the weight of which it does not greatly add, so that in fine weather bed and frame can be carried together into the open air without disturbing the arrangement of the suspension. It can be used on both sides of the ward simultaneously, can be dismantled as soon as done with, and stored in a small space. But apart from this, it provides satisfactory attachments for the suspension and extension of any fracture of the upper or lower limb.*

In the case of the army beds which have no rail at the end, it would not be easy to attach such a frame to the bed itself. All requirements are, however, satisfied in such a case by three overhead bars of wood or stout gas-piping running the whole length of the ward. One is placed vertically above the shoulder, one at the level of the groin, and one at the level of the foot. Such bars may be fixed to the rafters supporting the roof (*Fig.* 147). Should any intermediate extension point be required (which is not often), it can be obtained by laying a 6-ft. wooden bar across two of the longitudinal beams, or by suspending a pulley between two beams with extension cord.

* Since writing the above I have seen in the *Manual of Splints and Appliances for the Medical Department of the U.S. Army*, compiled by a board of medical officers appointed to investigate the different forms of apparatus in use for the treatment of fractures, the following statement (p. 27): "After considerable investigation, the board has been convinced that the Blake pattern of quadrilateral frame erected over the bed has all the merits of the more cumbersome frames, and the following advantages: (1) Lightness of construction; (2) Cheapness of construction; (3) Increased rigidity in proportion to weight; (4) Economy of space; (5) Ease of adjustment for different positions.

If these overhead beams are used, it is necessary also to have some means of taking a horizontal pull at the foot of the bed. This is provided by a very simple frame (*Figs.* 146, 147), which is an amplification of one seen at No. 2 Red Cross Hospital, Calais, made portable and adjustable, and adapted to the army bed. It allows of extension at any desired angle of flexion or abduction, combined with any required tilt of the bed. It folds up flat, and can be stored easily and erected instantly.

The frame consists of a main member (A) and a supporting strut (B). B is united to A by strong hinges (1) at the sides, and furthermore a tongue (2) in the upper ends of the side bars of the strut B fits into corresponding slots in the side bars of A, locking the two firmly together when extended. A stout hook (3), fastened to A and fitting into a ring in B, makes the whole absolutely rigid when erected. In addition there is a movable cross-bar (4), which is attached to the holes in A by bolts and wing-nuts.

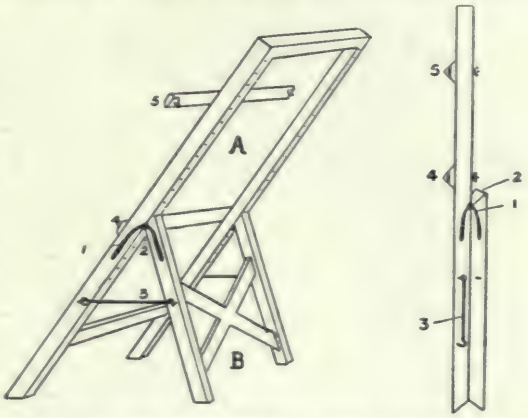


FIG. 146.—Frame—shown erected and folded—providing for a horizontal pull at the foot of a bed.

In use, the cross-bar (4) is put at the desired height, and the two iron side bars of the army bed are rested upon it. They are held laterally by the side bars of A, and are prevented from slipping back by the locking of their projecting knobs against the edge of the cross-bar (4). The extension pulley is attached to the top cross-bar of A. Should extension be desired with very little tilting of the bed, another cross-bar (5) is attached to A at the required height, to which bar the pulley is attached. With this combination of longitudinal beams and extension frame, all the requirements for the treatment of any fracture, whether of the upper or lower limb, are satisfied.

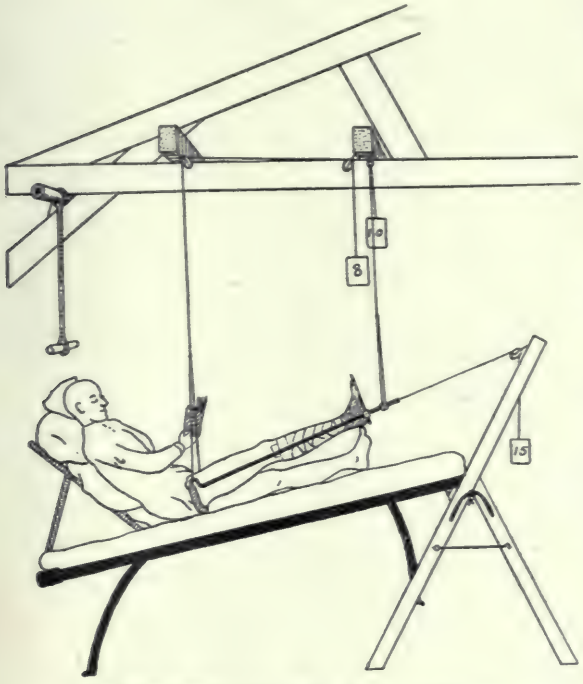


FIG. 147.—Scheme of extension for fractured femur.

Fractures of the Lower Limb.—Having discussed at some length the principles involved in the treatment of fractures, I do not suggest touching upon detail as regards the treatment of fractures of the lower limb. Suspension and weight traction can be applied in many ways, and the splint matters less than the way in which it is used. *Fig.* 147 illustrates the scheme of suspension in the case of a fracture of the femur, and shows the Calais frame and the longitudinal suspension bars in use. The splint is suspended by two cords only, attached by a running reef loop to two lengths of cord fixed

respectively to the upper and lower ends of the splint. By such an arrangement the splint is adjusted in the horizontal plane, and has then no further tendency to tilt. The Thomas splint is often suspended by four independent cords, to which are attached weights, which must be altered as needed in order to counteract the tilting which inevitably occurs.

The method illustrated has two obvious advantages over that of using the patient's own weight as the extending force.

1. The patient is comfortable. He can have as many pillows as he wishes, he can sit up to read or write, and he can move up or down the bed. He is less likely to develop chest complications. Yet he cannot increase or diminish the action of the extending force in the slightest degree, unless he brings the bottom of his splint down to the extending pulley on the frame. In a tilted bed this never occurs.

2. The method is as nearly automatic as anything can be in surgery. Lateral alinement looks after itself, and length looks after itself. The bone when united will not be too short, and, what is almost as important, it will not be too long, for the intramuscular fascial planes are strong structures, and it requires gross overpulling to lengthen them. The only thing that has to be combated is the tendency to backward sagging at the site of fracture.

Fractures of the Upper Limb. — Whatever difficulties there are in the application of splints to war fractures, these difficulties are much greater in the case of the humerus than of any other bone. Its upper third is enveloped by the muscles of the axillary folds and cannot be satisfactorily controlled by a splint. The shoulder girdle is impossible to fix. Not only is it extremely movable itself, but it is mounted upon that part of the trunk which is subjected to the greatest amount of movement. Here counter-extension is seen at its worst. The pull which is exerted depends entirely upon the amount of flexion or abduction of the arm relative to the trunk. Two diagrams (*Figs.* 148) make this point sufficiently clear. The humerus and the Thomas splint are drawn to scale. It will be seen that the distance between the two fixed points differs by as much as three or four inches in the extreme positions.

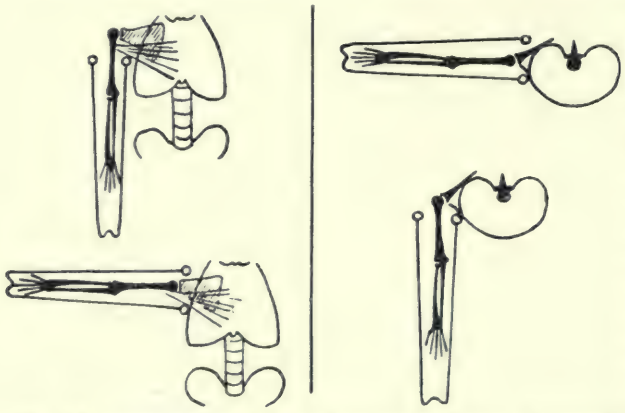


FIG. 148.—Diagrams showing effects of abduction and flexion of humerus in altering the distance between the fixed points in counter-extension.

The reason that counter-extension is so frequently employed in the treatment of the fractures of the humerus is that this method allows the patient to walk about with an ununited fracture. It appears to me that the case for ambulatory treatment is based upon an inverted view of cause and effect. It is argued that the improvement in a man's general health resulting from fresh air and exercise reacts favourably upon the progress of his wound. But the quickest way to get a man well is to remove the cause of his illness, and is therefore, in this case, to overcome sepsis and get the fracture united as soon as possible. The only certain means to attain this end is by providing adequate fixation. No splint properly controls a fracture of the humerus in both the walking and recumbent positions, and even the most ambulatory of patients spends eight hours out of the twenty-four in bed. The value of a method is shown, not by the date at which it allows the patient to walk about the hospital, but rather the date at which it allows him to walk out of the hospital cured. Judged by such a standard, the treatment of fractures of the humerus by simple weight-extension, as used by Blake, is one of the most strikingly satisfactory things in war surgery. The results obtained are excellent, and the effect of

continuously correct apposition of the ends of the bone, combined with slight movement at the seat of fracture, is that union is obtained remarkably early. So treated, it is common enough to see a fracture of the humerus united at the end of twenty-five days, in perfect position, with a full range of all movements at the elbow-joint.

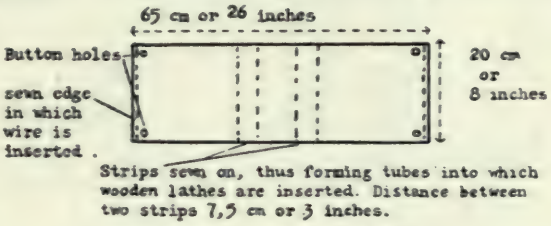


FIG. 149.—Diagram of canvas sling.

If a fracture of the humerus is treated by weight extension, a splint is no aid, but rather a hindrance. However, there are the natural splints, the muscles, lying in correct position, and only waiting to be put on the stretch to spring into instant action and force the fractured bone into correct alinement.

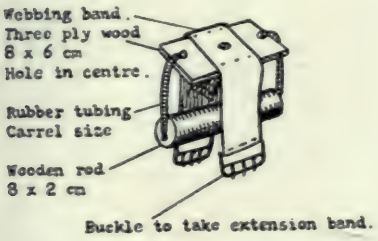


FIG. 150.—Diagram of finger exerciser.



Take, for example, the case of a fracture of the upper third of the humerus, where the deltoid is pulling the lower fragment outwards, and the pectoralis major, teres, and latissimus dorsi are pulling the upper fragment inwards. To try to push the fragments into position by local splinting, e.g., by Middledorf's triangle, is distinctly unsatisfactory. The command of the fragments is poor, and the distorting forces are not under control. The remedy is on the spot, and only needs to be used. The long head of the biceps lies between the tendons of the pectoralis major and teres; once it is put on the stretch, it pulls them back into line. The coracobrachialis and short head of the biceps splint the fracture internally, the deltoid is converted by traction from a distorting agent into an external splint, and posteriorly the outer head of the triceps bridges the gap and completes the series of natural supports.

In the treatment of fractures of the humerus, two additional pieces of apparatus are used: (1) A canvas sling, explained in the diagrams (*Figs.* 149, 151, 152); (2) A finger exerciser, useful but not essential. This, too, is self-explanatory (*Figs.* 150, 151, 152).

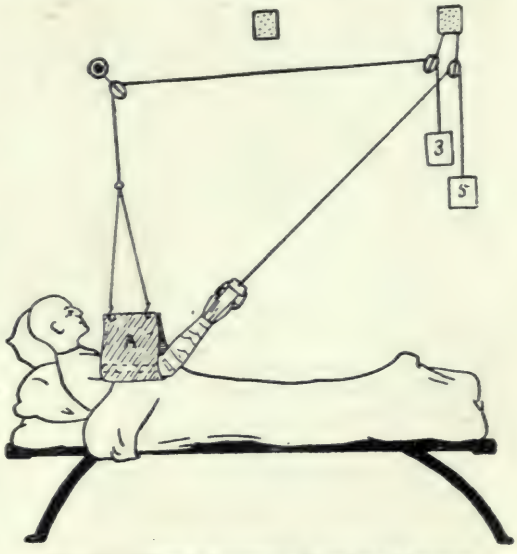


FIG. 151.—Scheme of extension of fracture of humerus, middle or upper third.

The method of slinging fractures of the humerus is more easily explained by diagrams than by verbal description. *Fig.* 151 shows the canvas sling, finger exerciser, and overhead bars. The weights shown are those usually required. As in fractures of the femur, it is best to overcorrect the tendency of the fracture to sag, and to reduce the weight later if it is found to be excessive.

In fractures just above the elbow-joint, a flexed position is desirable. When the limb is slung in this position, the forearm comes to rest in a position of three-quarter supination, and any trouble with fixation of the elbow in an extended position is avoided. In *Fig.* 152 a Calais frame is used to take a pulley carrying the extension cord from a figure-of-eight sling around the elbow.

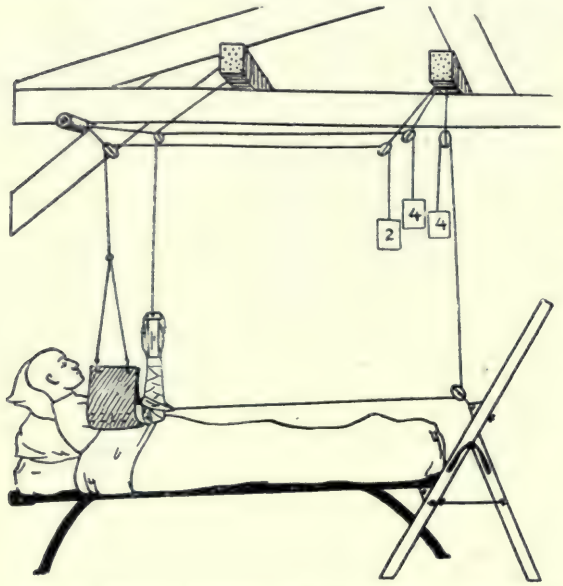


FIG. 152.—Scheme of extension of fracture of humerus, lower third.

Fractures of the Forearm and of the Wrist.—Just as in fractures of the tibia and ankle it is necessary to fix the knee, so in fractures of both bones of the forearm it is necessary to fix the elbow. Hence, even with weight extension, a splint is required. I use an adaptation of the Blake leg splint for this purpose (*Fig.* 153). It will be seen that it is very similar to the leg splint, except that it is lighter—of 7 mm. iron—is bent at an angle of 100 degrees, the U-piece is set at right angles to the side bars, and the side bars are strengthened 15 cm. beyond the bend by a cross-hoop welded on to them. The width between the bars is 12 cm., the length from the U-piece to the angle 19 cm., and from the angle to the lower end 65 cm. The cross-piece is identical with that for the leg splint, except for its size. The U-piece is padded with flannel covered with leather.

For the treatment of fractures of the forearm, an ordinary coat-hanger is attached to the under aspect of the side bars of the splint by two screw-rings, so that it can glide freely up and down. A cotton glove is glued to the hand, and a piece of cord tied to the tip of each of its fingers. Slings are then arranged along the splint, the arm is laid in position, and the upper arm held by a firm bandage. The forearm is now put in a position of full supination, and in this position the strings from the fingers are tied to the coat-hanger. The splint is now hung from the beams (*Fig.* 154), a weight of 4 lb. being usually sufficient, as the extension takes part of the weight of the limb. Finally,

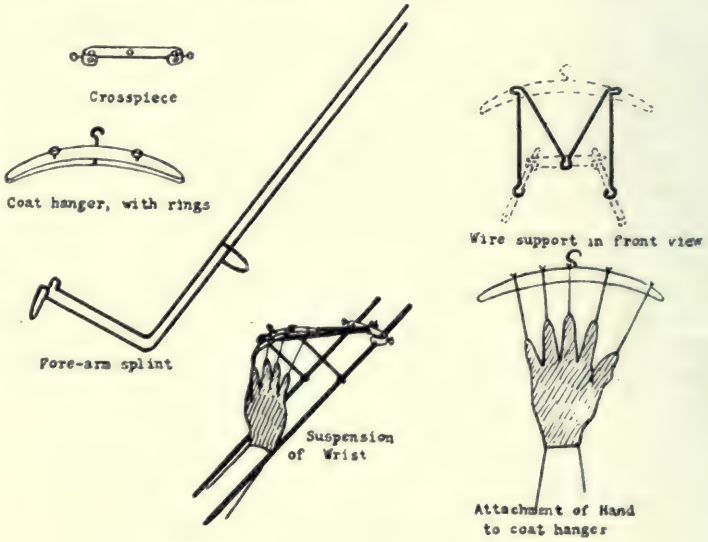


FIG. 153.—Apparatus for fractures of forearm.

a cord is attached to the hook of the coat-hanger, led through the central hole in the cross-piece, taken over a pulley on the lower roof beam, and a weight of 4 lb. is attached. Thus, continuous extension is secured in a position of full supination.

In the treatment of fractures of the wrist, where for some reason the patient must be treated in bed, the same coat-hanger is attached by the same screw-rings to a wire frame resting on the side bars of the splint, and clamped in position by the bolt in the cross-piece (*Fig.* 153). Suspension of the splint as a whole is all that is required to obtain dorsiflexion combined with moderate extension.

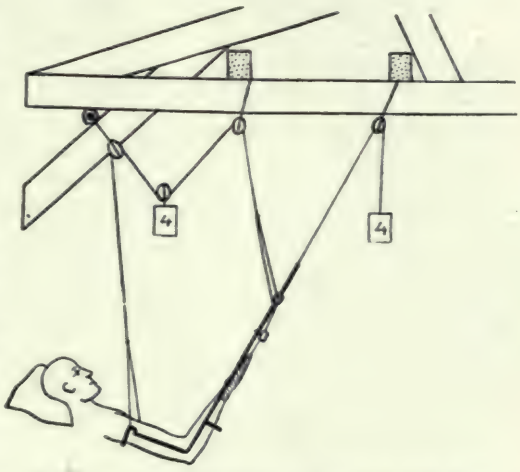


FIG. 154.—Scheme of extension of fracture of both bones of forearm.

CONCLUSIONS.

It may be said that it matters little what particular type of frames, or even of splints, is used; what matters is the way they are used. I have described the Blake splint which we used at Revigny, not in order to urge its adoption, but with a view to pointing out that our use of the Thomas splint is largely due to an unquestioning acceptance of an already existing apparatus. Weight traction is one of the oldest of methods, but it has nevertheless been largely lost sight of, and it is only by a series of steps, each following logically upon the last, that one has been led to the rediscovery that it is, after all, the best of methods. These steps have been :—

1. The use of one's favourite pre-war methods.

2. The adoption of the Thomas or some similar splint, used for the application of traction by means of counter-extension.

3. The discovery that results, though better, are still far from perfect. The pull is therefore increased, perhaps by screw traction, with resulting discomfort to the patient, development of pressure sores, and with not much better results.

4. To relieve this pressure on the skin, the bed is tilted and the splint tied to its foot, or weights are attached, primarily with the object of diminishing the pressure on the tuber ischii.

5. By stages of increased weight-pull it is discovered that when the ring is pulled right away from the tuber ischii, not only does no harm ensue, but almost perfect results are obtained.

6. Weight traction is substituted as a definite line of treatment.

7. One's ideas of splints are revised according to the new principles used. Much traditional apparatus is consequently discarded, and methods are progressively simplified in the light of experience.

THE DIAGNOSIS AND TREATMENT OF INJURIES TO THE CRUCIAL LIGAMENTS.

By Major S. ALWYN SMITH, D.S.O., Cardiff.

Up to the last ten years very little has been written concerning injuries to the crucial ligaments, and references in literature concerning the operative treatment for the condition have been scanty, and practically non-existent regarding the mechanism which produces the injury. References to the immediate suture of ruptured crucials have been made by Mayo Robson, Battle, Pagenstecher, Robert Jones, and Hogarth Pringle.

Pagenstecher, Honigschmied, and Dittel have written concerning the experimental rupture of these ligaments. In 1907, Hogarth Pringle described a case of rupture of the anterior crucial with avulsion of the tibial spine treated by operative means ; this was the first instance described in which the rupture had involved the bony attachment of the ligament. About this time I was taking many radiograms of knee-joints for Sir Robert Jones during my association with him, and we were struck by the fact that intra-articular fractures were commoner than was anticipated, and that whereas some were connected with crucial ligament injuries, others showed no signs of any such ligamentous damage. The injury causing the damage to the knee-joint was in many cases almost identical ; but whereas one patient sustained a sprained or torn anterior crucial, another would display a fractured external tubercle of the spine with no signs of crucial ligament injury.

Our investigations on the matter were collected and published in the first number of this Journal in 1913. The rôle of the crucials in sustaining the integrity of the knee-joint has not been fully recognized, although Corner, in an excellent paper on the surgery of the knee-joint published in 1914, pointed out the importance of the crucials in bearing strain in all movements of the knee. From the surgical standpoint the anterior crucial is more important than the posterior, as it is very much more liable to damage ; in fact, one may say that the posterior crucial almost invariably escapes, except in those severe injuries that are connected with dislocation of the knee.

Since the war began, the question of anterior crucial injuries has been more forcibly brought to our notice on account of the great number of bad knee-sprains that we are seeing ; this is doubtless due to the hardships of active service. 'Shell bursts' on the parapet cause men to be partially buried or forcibly thrown off their feet in various ways. 'Shell hole' cases, where men heavily equipped fall into muddy holes at night when going 'up' on ration parties, are obviously apt to cause more severe knee-joint injuries than ever come off the football field.

I wish to draw attention to the importance from the military standpoint of the sprained anterior crucial ligament in connection with injuries to the internal semilunar cartilage, and to emphasize that this is the main reason why operations for the removal of the internal semilunar cartilage have sometimes proved so unsatisfactory in the soldier. With regard to this point, I will speak more fully when describing the 'rocking' knee as the main symptom of the stretched anterior crucial ligament.

Anatomy.—The crucial ligaments extend from the intercondyloid notch of the femur to the non-articular area on the upper surface of the tibia. They are about the thickness of a slate pencil, and are invested by a prolongation of the synovial membrane, so that they are excluded from the synovial cavity although intracapsular. The anterior crucial is attached above to the inner side of the external femoral condyle at its posterior part. It passes downwards, forwards, and slightly inwards, and becomes fixed to the superior surface of the tibia in front of the internal tubercle of the spine, to the base of which a few of its posterior fibres are attached ; it is also attached to the anterior horn of the external

semilunar cartilage (*Case* 3). The posterior crucial springs proximally from the anterior part of the outer surface of the inner femoral condyle, and passes downwards, backwards, and slightly outwards to the posterior rounded surface of the non-articular area of the superior surface of the tibia (posterior inter-condylic fossa), to which it is fixed.

The knee-joint is composed of three separate articulations, two femoro-tibial and one femoro-patellar. The two crucial ligaments are lateral ligaments of the femoro-tibial joints. The ligamenta alaria and ligamentum mucosum are the remains of the partition between the separate synovial cavities of this joint. Not infrequently one finds the ligamentum mucosum as a sheet extending backwards to become continuous with the layer of synovial membrane involving the crucial ligaments, thus isolating the two lateral synovial cavities (Paterson).

Mechanism.—It should be realized that the stability of the knee-joint depends upon the integrity of (1) The muscles acting on the joint, with their aponeurotic expansions ; (2) The capsule of the joint, and its reinforcements, the lateral and posterior ligaments ; (3) The semilunar cartilages ; and (4) The crucial ligaments.

Each and every one of these structures is dependent upon the other. The crucial ligaments stand a large amount of strain in any abnormal movements of the knee-joint. The anterior crucial is tight when the joint is extended, becomes slack in semiflexion, and tense when the joint is fully flexed. The posterior crucial is tight in full flexion, becomes slack in semiflexion, but with the joint in full extension the ligament again tends to become tense. It is thus seen that in full extension of the joint the anterior crucial prevents antero-posterior mobility of the joint, and the posterior one fulfils the same rôle in full flexion of the joint. The amount of tension, however, is merely relative, as can be easily demonstrated by forcibly pulling and pushing the head of the tibia on an anæsthetized person with the knee in semiflexion. It is found that the amount of sliding of the tibia on the femur is very slight.

Extension of the joint is limited by : (1) The hamstring muscles ; (2) The ligament of Winslow ; (3) The lateral ligaments ; (4) The anterior crucial ; (5) The posterior crucial. The most important are the ligament of Winslow and the anterior crucial. Rotation is prevented in the extended position by all the ligaments before mentioned. In semiflexion a certain amount of internal rotation is allowed, on account of the relaxation of the anterior crucial and the internal lateral ligaments. Paterson is of opinion that internal rotation is mainly limited by the crossing of the crucial ligaments, the anterior pressing on the tightening posterior.

In the semiflexed position external rotation is comparatively free. It is limited by the superficial fibres of the internal lateral ligament to a certain extent, but mainly by the deep attachment of this ligament to the internal semilunar cartilage (the coronary ligaments). The anterior crucial and the external lateral ligaments have no limiting action at all. Paterson thinks that the posterior crucial ligament limits this rotation as it becomes tightened. This I have not been able to verify clinically (*Case* 4).

Adduction of the knee is limited by the external lateral ligament and the posterior crucial, aided by the wedge-like semilunar cartilages. Abduction of the knee in the fully extended position is limited by the superficial fibres of the internal lateral ligament. When the knee is semiflexed more than 20 degrees, these fibres pass out of action, and the main source of stability is now (1) The deep internal lateral ligament ; (2) The anterior crucial ligament. Lateral sliding of the knee is prevented by the crucial ligaments, and by the semilunar cartilages on account of their wedge-like shape, and also by reason of their attachments to the lateral ligaments. All fibres of the lateral ligaments also assist in preventing sliding movements.

The commonest form of knee sprain combines abduction of the knee with external rotation of the tibia, the knee being in the semiflexed position. The deep fibres of the internal lateral ligament attached to the internal semilunar cartilage become torn, and the cartilage either fractures or is displaced. Should the abduction of the knee continue further, the entire strain is borne by the anterior crucial ligament, which becomes in its turn stretched or torn, or the internal tubercle of the tibial spine becomes avulsed.

It is obvious that the severity of the lesion to the anterior crucial ligament is dependent upon the strain to which the knee is exposed. When one examines a knee-joint which has sustained an injury that betokens a damaged internal semilunar cartilage, the examination is not complete without verifying the integrity of the anterior crucial. Rotation outwards is always more obvious after removal of the internal semilunar cartilage, as is also abduction in the semiflexed position (*Case* 4).

Several cases have been seen where the cartilage has been removed and the symptoms of locking have been relieved, but the weak 'rocking' knee has remained. In each case the patient was of opinion that the laxity of the knee was due to faulty operation, until the true nature of the injury was explained to him. It is thus expedient to safeguard oneself by a thorough examination to verify the structures that are damaged. Where there has been an avulsion of the tibial spine, the symptoms of laxity are often masked ; on account of the new bone formation there is inability to fully extend the knee, and forward sliding of the tibia is prevented. During operation for this condition, with the muscles acting on the joint relaxed under the anæsthetic, the anteroposterior mobility of the tibia manifests itself markedly.

Clinical Manifestations.—The following types of lesion may occur :—

A. Due to Direct Trauma.—(1) Rupture or stretching of both crucials, due to grave injuries to the joint such as dislocations of the knee ; rarely the crucials may be destroyed by gunshot wounds passing laterally through the joint. (2) With bony involvement—avulsion of the tibial spine—anterior crucial only. (3) Combined with torn or displaced internal semilunar cartilage—anterior crucial only. (4) Rupture or stretching of one crucial ligament without other damage—uncommon in anterior, rare in posterior crucial.

B. Due to Mechanical Causes (Indirect Trauma).—(5) Genu recurvatum—producing laxity in both crucials—anterior more than posterior.

Crucial laxity may also occur :—

C. Due to Disuse.—(6) Inflammations in or around the knee-joint—the lateral ligaments are more apt to suffer, the crucials generally escape (*Case* 6). (7) Disease or trauma of hip requiring long immobilization—the same results are found as in (6).

D. Due to Disease.—(8) Charcot's disease—generalized disintegration of all ligamentous structures connected with the joint.

In classifying lesions of the crucial ligaments, it is important to remember that tearings are always due to severe trauma, but that stretchings can occur as the result of continued strain due to mechanical causes. Disuse of the knee-joint apparently affects the lateral ligaments more than the crucials, and continued extension, as in the treatment of fractures of the femur, has the same result—the crucials appearing little the worse. Charcot's disease affects all ligaments of the knee to a similar extent, and an extreme flail-like joint results.

From the clinical aspect, the anterior crucial is of greater importance than the posterior, being more liable to injury. The combined rupture of the external lateral ligament and lax posterior crucial is a rare condition, and I only remember having seen one or two cases.

A stretched anterior crucial is almost invariably associated with a torn internal semilunar cartilage, except where the injury has been a forcible hyperextension of the joint that has stretched the ligament of Winslow and the anterior crucial at the same time ; this type of case is rare, but if the case is of long standing, genu recurvatum will be present and the tibia can be brought forward on the femur in the hyperextended position. Conversely, the anterior crucial may be gradually stretched in malunited fractures of both bones of the leg, set with an anterior concavity. Here the body weight is thrown behind the centre of the knee-joint, and the anterior crucial and the ligament of Winslow have strain thrown upon them at every step taken (*Case* 5).

In avulsion of the tibial spine, where the cause is usually a fall in the flexed and internally rotated position of the tibia, the internal semilunar escapes as a general rule, although it is not an uncommon history to find that a displaced cartilage has been diagnosed and even operated upon, the true condition having remained undiagnosed. It is essential that all cases that display inability to extend the joint fully should be radio-

graphed, although the bone block of a tibial spine case should readily be diagnosed from the 'elastic' block of a displaced internal cartilage.

Rupture of the posterior crucial alone is very rare, and I have never seen a case.

Rupture of both crucials can occur in forward dislocation of the tibia with hyper-extension of the knee, and also where the tibia is dislocated backwards and upwards. Lateral dislocation has produced the dual lesion, and in addition there may be paralysis of one or both of the popliteal nerves. In all these cases of severe injury there is a flail-like knee.

When the tibia can be brought forwards on the femur in full extension, the anterior crucial is definitely ruptured. When the posterior crucial is ruptured, the tibia may be displaced backwards into the ham with the knee in full flexion.

In old-standing cases the anterior crucial may be found to be, not fully ruptured, but stretched and attenuated; to all intents and purposes the condition is quite as serious as a complete rupture, for secondary immobilization even for a prolonged period does not appear to strengthen it.

The stretched or torn anterior crucial combined with a tearing of the internal semilunar cartilage appears to be a commoner injury than is generally supposed. The diagnosis is made in old-standing knee-joint injuries by the combined symptoms: (*a*) Locking of the joint; (*b*) Rocking or slipping of the joint, combined with a feeling of insecurity. As will be seen from the reports of *Cases* 1, 7, 8, and 9, periodic lockings took place. There was marked abduction at the knee in semiflexion, and rotation of the tibia externally, and to a lesser extent internally, was increased; the tibia could in each case be brought forward on the femur in the extended position. The removal of the cartilage cures the 'locking,' but will, if anything, increase the rocking and slipping of the tibia on the femur. *Case* 4 is a good example of this point. Here the strain was purely a lateral one involving the inner side of the knee. The distal attachment of the deep internal lateral ligament did not give way, but brought a piece of the articular edge of the internal tuberosity of the tibia with it, producing a rare example of a sprain-fracture of the deep internal lateral ligament. The internal semilunar cartilage was obviously displaced *in toto*; this is well seen in the photograph of the specimen (*Fig.* 158). All strain was now borne by the anterior crucial, which became stretched. After the loose bone and the attached semilunar were removed, the general laxity of the joint increased, as will be seen in *Figs.* 159, 160.

TREATMENT.

Generally speaking, the immediate treatment of injuries to crucial ligaments should be conservative rather than operative. Recent injuries to the joint that show abnormal mobility should be *x*-rayed as a routine. This will eliminate avulsion of the tibial spine. Where there is rupture of both crucials due to lateral or posterior dislocation of the knee, the limb should be immobilized with the knee flexed to 20 degrees for at least three months, but faradism to the quadriceps and general massage with movements of the patella should be practised daily. Good results have been reported by many observers from treatment by prolonged fixation of the joint. Should there be, as sometimes happens, a paralysis of one or both of the popliteal nerves due to stretching, postural and electrical treatment for the nerve injury must also be undertaken. Where there is a recent avulsion of the tibial spine, despite the advice of Hogarth Pringle, I think it is wise to try the effect of immobilization of the knee in the fully extended position for twelve weeks, combined with the massage and faradism as mentioned above, rather than to treat the case by primary operation and fixation of the detached ligament and its bony insertion. In cases of old standing, however, operative measures are indicated.

Prolonged immobilization can be carried out equally well by means of splint or plaster of Paris. The former is, I think, preferable, in that massage can be carried out more fully in the early stages when the patient is confined to bed. After three or four weeks the long skeleton splint can be substituted by a Thomas calliper, which will enable the patient to get about with comfort.

Secondary wasting of the quadriceps, especially the vastus internus, will not be so pronounced and will not require such prolonged after-treatment to restore this musculature to its previous tone if massage and faradism are instituted at once.

The after-treatment of anterior crucial injuries can generally be undertaken by means of appliances. In the ordinary course of events a Marsh cage splint will pervent the abnormal mobility that is present when one or other of the crucial ligaments has been ruptured or stretched. This, of course, means that the appliance will require to be worn for an indefinite period. In conjunction with the cage splint, a Japanese crêpe bandage wound around the knee will often be beneficial as an additional security. In anterior crucial cases the boot should be raised both sole and heel on the inner side, to throw the strain against the external lateral ligament and prevent any tendency to abduction at the knee or rotation outwards of the tibia on the femur. The 'rocking' knee that has been operated upon for a loose internal semilunar cartilage, and whose symptoms are now those of a lax anterior crucial ligament, may be dealt with in this way if no operation is desired. This, however, is the type of crucial ligament injury that it is advisable to help by operative means, as the thought of always wearing a mechanical support is repugnant to many young men, and the inability to take part in games and athletics is a prime factor in the desire for radical treatment. It was in cases of this description that in 1916 I attempted plication in one case and the insertion of a silk ligament in another. Both these operations failed somewhat ignominiously. However, I intended to substitute an intra-articular tendon fixation should another case present itself. My idea was to utilize the biceps by threading it from femur to tibia in the course of the anterior crucial ligament, or to use the semitendinosus by dividing it in the thigh and then threading the distal end from tibia to femur, fixing the upper free end at the upper and outer side of the femur. However, before these ideas could be tried out, Hey Groves brought out his fascial ligament operation, which is undoubtedly a great advance on anything that has been done before. It is early yet to speak of after-results; but so far as my own four cases are concerned, the results of the operation, somewhat modified from that described by Hey Groves, justify continuance of the procedure in certain selected cases.

Operative Treatment of Anterior Crucial Injuries.—The following operations have been done at varying times, apart from those of immediate suture of the ligaments as mentioned before: (1) Plication; (2) Reefing (Corner); (3) Wire loops (Corner); (4) Silk ligament substitution; (5) Fascial substitution (Hey Groves).

1. My experience in plication of a stretched anterior crucial ligament is limited to one case (*Case* 1), and the result did not justify a repetition of the operation. As will be seen from the report, the ligament was found at the operation to be thinned and markedly lengthened, so much so that with a blunt hook one was enabled to bring the ligament forwards to a considerable extent with the knee in flexion. The ligament was split longitudinally, and each lateral half was pulled outwards, thus making the ligament diamond-shaped. This diamond was stitched with chromic catgut into the shape of a Maltese cross, in the same manner as one frequently shortens a tendon.

The result at the time appeared satisfactory, and the knee became appreciably more stable. After prolonged immobilization the clinical result was very unsatisfactory, the weakness of the leg being as apparent as it was before the operation was performed. The lack of control was so marked that, despite the use of a cage splint, the patient asked that an arthrodesis of the knee should be done. This operation was performed four months after the one referred to for the shortening of the ligament, and it was interesting to remark the changes that had taken place in this structure. The ligament appeared shorter than at the previous operation, but its consistency was soft and jelly-like, akin to myxomatous degeneration; on putting a blunt hook behind the ligament and pulling on it the ligament readily tore in half.

2. Edred Corner devised a reefing operation in which he took up the slack of the ligament by means of a non-absorbable suture which was passed round the ligament and fixed through holes drilled in the condyle of the femur. This operation seems to give little chance of permanent improvement, as the atrophic ligament is too weak to maintain the stability of the joint

3. Corner also described an operation for the replacement of an anterior crucial ligament by means of two loops of wire, one of which is fixed through the external condyle of the femur, and the other through the internal tuberosity of the tibia. The utility of this operation appears to be very limited, as one feels that the result would be, to say the least, very transitory, on account of rarefying osteitis around the wire.

4. Another case of anterior crucial rupture came under my care, and the use of the cage splint was found to be insufficient. The question of suture of the ligament or arthrodesis of the knee was discussed with the patient, who preferred the chances of the former operation. As will be seen by the case history, the ligament was found to be torn from its tibial attachment, and its condition was such that the whole of it came away with gentle traction by forceps. The degenerated ligament was very soft and friable.

The idea of a silk ligament presented itself, and the principles underlying Lange's work on tendons seemed to hold good. The external femoral condyle was drilled, as was the tibial tuberosity, in the manner devised by Corner. Eight ply of silk were pulled through the channels thus made, and the new ligament was fastened at its upper and outer aspect by a wire keeper which was hammered into the bone. The flexed tibia was pushed backwards on the femur as far as possible, and the silk was knotted and stitched to the periosteum on the antero-internal surface of the tibia, and, to make doubly certain, was also stitched to the infrapatellar tendon. After the wound was stitched up, the stability of the knee-joint appeared to be normal.

The progress of the case was uneventful for fourteen days, but the joint was immobilized for eight weeks. A certain amount of synovitis persisted, but when passive movements were begun about the tenth week the synovitis was more noticeable. About the eleventh week a small sinus appeared at the lower end of the wound, and the temperature became elevated. The knee-joint was freely opened for the purpose of producing drainage and subsequent ankylosis. The whole joint was extremely congested, the inflammation being not only in the synovial membrane (including the fat pads), but in addition the cartilage was decidedly pink and non-articular portions of the joint were tremendously injected. All the tissues to which the silk had been tied were friable, and the same condition was noted as in the previous case—to wit, the myxoma-like appearance of the tissues. The arthritis was evidently due to the silk acting as a foreign body.

After the lack of success of the silk ligament scheme, it was resolved that should another case present itself which could not be satisfactorily treated by conservative measures, we should use the tendon of the biceps, in whole or in part, or the semitendinosus, to make a new anterior crucial ligament.

5. No case, however, appeared until Hey Groves brought out his operation of substituting a strip of fascia lata for the crucial ligament. This operation was described in the *Lancet*, 1917, Nov. 3, p. 674, and appears to be a great advance on anything that has been done before. From the clinical standpoint, I think the operation is incomplete, in that it does not attempt to strengthen in any way the internal lateral ligament, so that the new fascial strip has to bear the entire strain of abduction of the knee as well as of anterior sliding and internal rotation of the tibia on the femur. It seemed advisable to attempt to reconstruct the deep fibres of the internal lateral ligament in some way, and the autogenous transplant of fascia lata was the first idea that presented itself.

I reconstructed an external lateral ligament of the ankle-joint in an extremely bad old-standing case of sprained ankle that had required the use of an appliance. The result was very satisfactory. I then tried the same experiment in a case of extreme lateral mobility of the knee due to a bullet wound of the knee-joint, of sixteen months' standing (*Case* 6). In addition, I divided the sartorius four inches above its insertion and brought the free distal end beneath the periosteum in the region of the adductor tubercle. The result of this case was also very gratifying. The first of a series of four anterior crucial reconstructions had, in addition, a sartorius fixation, but no fascial transplant. It then became apparent that the operation could be much simplified, and that the same strip of fascia lata could be made to take the place not only of the anterior crucial ligament,

but also of the internal lateral ligament. The operation has been performed on three cases, and is carried out as follows :—

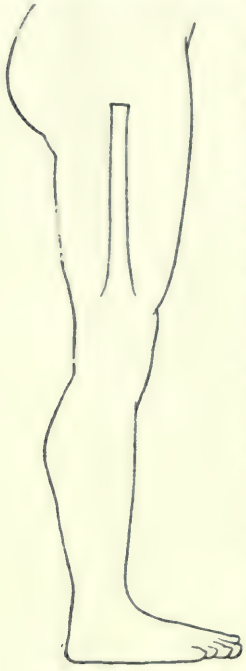


FIG. 155.—Diagram to show location and size of fascial strip.

The field of operation includes the region of the knee and the full length of the thigh. A tourniquet is applied at as high a level as possible on the thigh, the knee is flexed to 60 degrees, and a J-shaped incision is made as for an excision of the knee, the inner limb being about six inches in length, and the transverse portion of the wound passing across the tubercle of the tibia ; the outer limb of the incision must be at least twelve inches in length. The incision passes through the skin and fascia only. The flap is now dissected upwards over the patella ; all the skin edges are covered in and clipped with wound towels. The patella is divided vertically, and the two halves are separated. The anterior crucial ligament, covered by synovial membrane, is examined. The upper level of the suprapatellar pouch is now noted, as it is advisable that the fascial strip should pass through the femur at a slightly higher level to avoid any unnecessary intra-articular disturbances. A long drill with a diameter of $\frac{1}{4}$ in. is now bored through the internal surface of the external condyle at the site of the upper attachment of the anterior crucial ligament. The drill-hole must pass upwards and outwards, and should emerge through the shaft of the femur externally at the upper level of the suprapatellar pouch. The internal tuberosity of the tibia is now drilled in the same way, beginning slightly anterior to the insertion of the sartorius, passing upwards, backwards, and slightly outwards, and emerging on the superior articular surface of the tibia just anterior to the internal tubercle of the tibial spine. A strip of fascia lata $1\frac{1}{2}$ in. wide is now cut. This strip is attached at its bottom end, and in the ordinary course of events should be between $9\frac{1}{2}$ and 10 in. in length (*Fig.* 155).

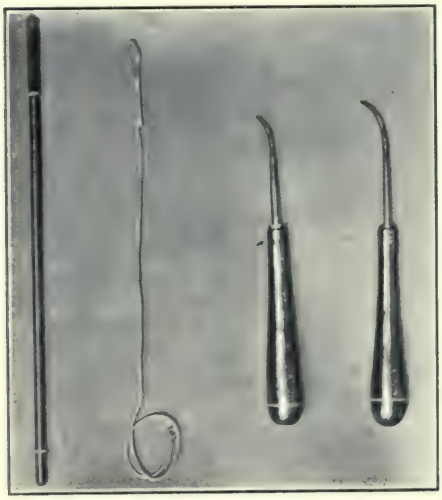


FIG. 156.—Drill, flexible probe, and shoemakers' awls, used in the operation.

The two lateral incisions in the fascia are joined at their upper end, and the new fascial ligament is stripped downwards from the subjacent muscle. A long flexible probe with an eye large enough to take the fascial strip is now pushed, eye first, through the tibial drill-hole into the knee, and upwards through the femoral drill-hole until it emerges on the outer side of the femur. The free end of the

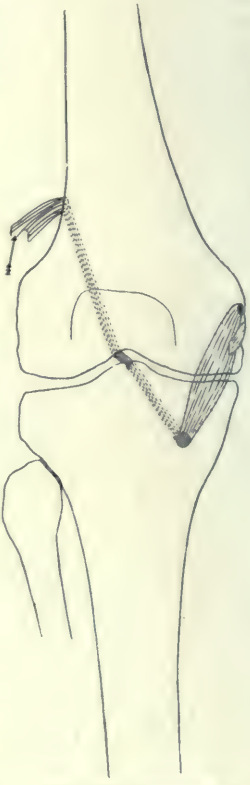


FIG. 157.—Diagram to illustrate course of new anterior crucial ligament.

fascial ligament is now threaded, and the probe is withdrawn, bringing the fascial ligament with it. As much tension as thought fit can now be applied to the new ligament, and the tibia is forced backwards on the femur as far as possible.

A channel from before backwards in the inner condyle of the femur about the adductor tubercle is now drilled. This cannot be easily done with a straight drill or bradawl, but is very simply made with the largest size shoemaker's awl, which makes a curved channel (*Fig.* 156). This can be enlarged to the requisite size. The free end of the fascial strip is then threaded through this channel from before backwards and pulled as tight as possible, both in its anterior crucial portion and also in the internal lateral part of its course, and is stitched to the periosteum around the tibial orifice, and also to itself after it has passed through the adductor drill-hole. Strong chromic catgut is the suture material of choice. The fascial ligament appears to curl on itself as it passes through the bone, and makes a ligament about the thickness of a slate pencil (*Fig.* 157). As Hey Groves points out, the tension of the attached portion of the strip is from below upwards, and consequently strengthens the external lateral ligament. The two halves of the patella are brought together, the leg is carried to a position of 20 degrees of flexion at the knee-joint, the tourniquet is removed, the hæmorrhage stopped, and the patella stitched together by three or four chromic-catgut sutures through the aponeurosis. A small cigarette drain is placed between the two halves of the infrapatellar fat pad, but not extending into the joint cavity. The skin edges are approximated by Michel's clips.

The leg is put up on a Thomas skeleton splint with a foot-piece, in a position of 20 degrees of knee flexion. The drain is removed in forty-eight hours. A certain amount of oozing continues until the third day, so a second dressing should be undertaken on the fourth day. At the end of a fortnight a cast is applied, still with the knee slightly bent. At the end of four weeks massage and faradism to the quadriceps begin, and gentle active movement is permitted; a support, however, should be worn for another fortnight.

Hey Groves has suggested the use of the semitendinosus tendon for the replacement of the posterior crucial ligament. It is carried out in the same way as his operation for anterior crucial substitution, the course of the posterior crucial ligament being followed by drill-holes. This operation is of greater difficulty than the one described above. On account of the rarity of posterior crucial injuries, this operation will have a limited field.

The surgery of the crucial ligaments is an interesting problem; it should, however, be reserved for selected cases, though the operation described appears to produce no more trauma in the knee-joint than the usual transpatellar operation.

SHORT NOTES OF NINE CASES.

Case 1.—**Stretched anterior crucial ligament treated by plication.**

Pte. G. History of having slipped and fallen while in trenches, March, 1915. The left knee was twisted. Not much pain till next morning, when knee was much swollen. Reported sick two days later, but kept on duty. Knee became worse, and locked on several occasions; these were accompanied by swelling. Was forced to fall out on route march on account of locking, pain, and swelling about April, 1915, and was then sent down the line. Ever since first strain in March, patient noticed a 'looseness' about the knee. Operation for removal of internal semilunar cartilage in a general hospital in England, May 17. No more locking of knee followed operation; otherwise there was no improvement, and great insecurity was felt in the joint.

On admission, Nov. 17.—Complained of leg always rotating externally when putting any weight on heel. Left knee shows marked extraneous mobility and hyperextension. Rotation of tibia outwards and inwards on femur increased. Old scar of previous operation on medial side of knee-joint. *X* ray normal.

Treated by altered boot, flannel bandage, and calliper splint, with massage and faradism to quadriceps for four months: no improvement. Cage splint was tried, but found quite inefficient, as the foot rotated externally at every step.

Operation, April 6, 1916.—Split-patellar arthrotomy through U incision. Anterior crucial ligament exposed and found to be very much thinned and stretched. The ligament was split vertically and plicated, the lateral halves being pulled outwards and the sides of the diamond thus formed stitched together in the shape of a cross. This procedure stabilized the knee-joint in antero-posterior mobility considerably. Convalescence uneventful.

After two months' immobilization joint was as unstable as ever. Patient desired an arthrodesis of the knee, which was done. At this operation, it was found that the anterior crucial ligament was very soft, friable, and swollen, appearing to the naked eye almost like a myxomatous degeneration. A point of surgical interest was that the articular surface of the patella showed no signs whatsoever of having been divided at the previous operation.

Case 2.—**Ruptured anterior crucial ligament treated by insertion of a silk ligament.**

Cpl. L. Sprained left knee while in training, December, 1914. After going to France had much knee trouble, the knee locking while marching, and in addition there was unnatural movement in knee with feeling of insecurity; as time went on this became more marked.

On admission, June 13, 1916.—Diagnosis of torn anterior crucial ligament made. It was decided to attempt to suture the ligament.

Operation, July 6.—Split-patellar arthrotomy through U-shaped incision. Anterior crucial ligament found to be torn from its tibial attachment. Free end of ligament was picked up with forceps, and entire ligament, which was obviously degenerated, came away quite readily. Tibial end of ligament found to be only $\frac{1}{4}$ in. long, and this too was soft and friable.

It was resolved to make an intra-articular silk ligament. A drill-hole was made from the non-articular outer surface of external condyle, parallel to joint and opening at the intercondyloid notch in region of the femoral attachment of anterior crucial ligament. A double wire was thrust through the hole from without, and the loop made to present in intercondyloid region. Eight ply of No. 3 silk now brought through this channel by means of the wire loop. Upper and outer end of silk knotted to a loop of phospho-bronze wire which acted as an anchor, and this was hammered into the bone so as not to protrude into joint. It was found impossible to stitch the silk to tibial end of the ligament, so another hole was drilled in an upward and backward direction from tubercle of tibia, the drill emerging at the tibial attachment of the anterior crucial ligament. By means of a wire loop the silk strands were brought out through this hole to front of tibia. The silk was pulled as tight as possible, well knotted, and also stitched through infrapatellar tendon. Wound was closed in usual way, and joint found to be quite stable, especially in antero-posterior movements of tibia on the femur.

Convalescence uneventful except for synovitis, which persisted, and when movements began after seven weeks it became more marked. Ligament operation unsatisfactory, as a sinus appeared after nine weeks which necessitated opening up the knee-joint and producing ankylosis.

Case 3.—**Avulsion of tibial spine of six months' standing. Removal of bone obstruction. Anterior crucial implantation.**

Sec. Lieut. F. The patient had a history of having sustained injury to left knee in May, 1917, by falling into a shell hole with the leg flexed underneath him. On being helped out knee was absolutely fixed, and he could neither bend nor straighten the leg. Pain was excruciating, and marked swelling immediately followed. Was sent down the line, remaining at a C.C.S. two days without any treatment; was then sent to a base hospital, where a box splint was applied; he remained there two days and was then sent to a hospital in this country. Was operated on for removal of internal semilunar cartilage in June. A posterior splint was used for one day only following the operation. Passive movements were begun in a fortnight. There was very little movement at this time. Massage was instituted and continued for six weeks, and very slight improvement in movement resulted. Was now sent to a Command Depôt, where whirlpool baths and massage improved matters somewhat. After four months 40 degrees of movement was present.

On admission, November.—Patient could flex knee to 40 degrees. Full extension was limited by 25 degrees, the obstruction appearing osseous rather than fibrous. No anterior crucial laxity could be elicited. *X* ray showed definite fracture of inner tubercle of spine of tibia, with new bone formation.

Operation, Nov. 27.—Joint exposed through split-patellar route. All excess bone on anterior part of tibial spine chiselled away. Anterior crucial ligament found to be fully separated from tibia, a few fragments of bone remaining attached to it. Ligament was held in position by its synovial covering, but a few of its most external fibres were found attached to anterior horn of external semilunar cartilage. Ligament embedded in the raw area of bone that remained after excess callus was removed. Knee found to extend fully, and after wound was closed in the usual manner the whole lower extremity was immobilized. Leg was kept immobilized in the extended position for twelve weeks to make sure of efficient union of ligament to the tibia. Knee now lacks 15 degrees of full extension, and there is limitation in flexion, but this is improving. There is no laxity in the joint.

Case 4.—**Stretched anterior crucial ligament, with fracture of portion of internal tuberosity of tibia, involving deep internal lateral ligament and semilunar cartilage.**

Sec. Lieut. S. Buried by a high-explosive shell, April 6, 1917. Was thrown on to his right side, and the weight of the earth fell on outer side of left knee with the leg bent. On being dug out there was much swelling of knee, which was very painful. During the next day or two the entire leg swelled and became discoloured owing to generalized bruising. Was sent down the

line. At Blackpool, about a month later, treatment by massage and ionization was begun, and continued for about three months, but synovitis persisted, though he could get about with knee rigid by aid of a stick.

On admission, Sept. 15.—*X* ray showed a loose piece of bone, evidently detached from articular margin of inner tuberosity of tibia. Constant locking of the joint took place on walking on uneven ground or taking a false step. Synovitis followed each derangement, and some fluid was always present in the joint. On examination, there was preternatural abduction at the knee, marked increase in rotation outwards, and slight increase in rotation inwards of tibia on the femur. Synovitis was present. Knee was kept at rest to reduce effusion preparatory to operation for removal of the loose piece of bone.

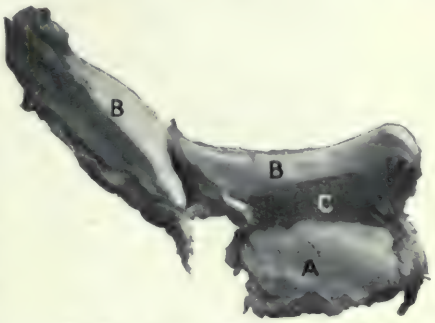


FIG. 158.—*Case* 4. Specimen removed from knee-joint. A, Superior articular surface of tibia. B, Internal semilunar cartilage. C, Suspensory ligament.

Operation.—A curvilinear incision was made over inner aspect of joint—longer than is usually employed for removal of the internal cartilage. On opening the joint capsule, fractured surface of the loose bone presented itself. With gentle traction on the fragment it came away easily, with little dissection. The whole of the internal cartilage was found to move with it. A complete circumferential tear of the cartilage had occurred, and the meniscus was attached to the joint at its anterior and posterior horns only. These attachments were divided, and the mass with attached cartilage was removed. The specimen (*Fig.* 158) shows that the bony mass consists of a thick flake of bone, mainly superior articular surface of tibia; but the suspensory ligament attaching it to the semilunar cartilage is intact. It is unfortunate that the semilunar had to be divided transversely to remove the anterior horn. As expected, locking of the joint was cured, but 'rocking' was increased (*Figs.* 159, 160).





FIGS. 159, 160.—*Case* 4. After operation, showing laxity of the joint.

The use of a cage splint combined with an altered shoe, after the tone of the quadriceps was improved by massage and faradism, brought about improvement, and patient was able to get about with comfort. The cage splint will require to be used for an indefinite length of time.

Case 5.—**Genu recurvatum due to malunited fracture of both bones of the leg, causing secondary stretching of the anterior crucial ligament owing to faulty mechanism in walking.**

Cpl. M. Injury received December, 1916. A 'dud' trench-mortar shell struck his left leg on outer side. There was fracture of tibia at junction of middle and lower third, and of fibula at two points 5 inches apart; no acute pain or swelling in knee at the time or since. Four unsuccessful attempts to reduce fracture, and finally tibia was plated at end of January, 1917. A fortnight later leg was put in plaster, and casts were continuously worn until May, when there were still no signs of union. Passive congestion and massage were now instituted, and continued until August. Plates were removed, and leg was reset and put in plaster again in September, the tibia being concave anteriorly.

On admission, December, 1917.—It was found that union had taken place in bad position. Tibia markedly concave anteriorly. There was a certain amount of valgoid deformity of the lower fragment, which was internally rotated as well. The tendo Achillis and tibialis posticus were contracted, and the peronei atrophic and weak, the foot being in a position of equino-cavo-varus. A boot and appliance were ordered, to throw foot into valgus position, the peronei were massaged and faradized, and patient was instructed to walk. A month later there was marked laxity of the anterior crucial. The tibia could be brought forwards on the femur, and rotation inwards was markedly increased.

Operation, April 12, 1918.—An osteotomy just above old site of fracture was performed, together with lengthening of shortened tendo Achillis and tibialis posticus.

Union in good position has occurred. Patient at present walking with a cage splint.

Case 6.—**Gunshot wound of suprapatellar pouch followed by marked lateral ligament laxity treated by autogenous transplant of fascia lata to reconstruct the internal lateral ligament.**

Lieut. P. Wounded September, 1916. Bullet entered anterior aspect of knee-joint in suprapatellar region and lodged in joint. Wound dressed seven hours after. Sepsis followed, and temperature reached 104°. Knee-joint aspirated three days after infliction of wound. Four days later, operation to remove the bullet, which was not found. Two days later another attempt was made which was successful—tube drainage for forty-eight hours followed. Dressed daily for two weeks and was then transferred to Malta. Here the joint was aspirated under general anæsthesia. Extension by means of a Balkan splint applied. After five weeks, transferred to England wearing posterior splint. Voyage lasted three weeks, during which time he wore a back splint and had daily massage. Between December, 1916, and May, 1917, was treated in two hospitals in this country by ionization, counter-irritation, and massage. Transferred to Command Depôt in May, where massage was continued, but in addition whirlpool baths and forcible flexion were instituted. Improvement in movement noticed.

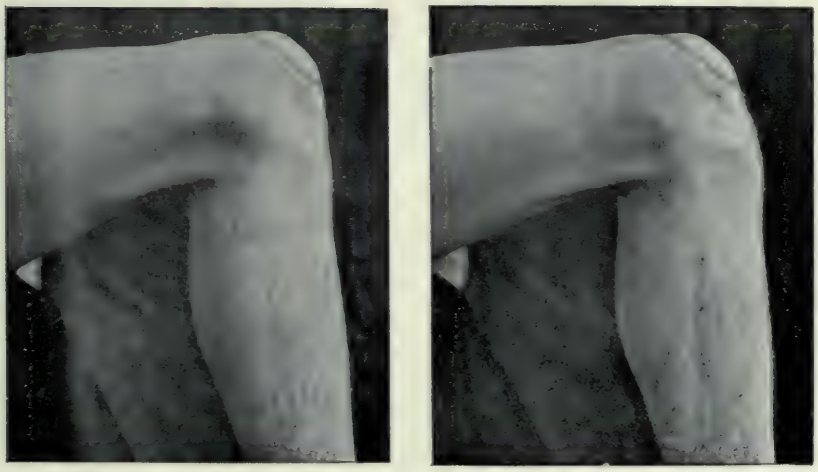
On admission, November, 1917.—All wounds healed—scars on both lateral and medial aspects of knee, which is swollen and weak. Extension full, flexion to 90 degrees, marked lateral mobility of joint, no crucial involvement. Massage and movements continued for two months, with altered shoe to relieve strain on internal lateral ligament. No improvement in lateral mobility.

Operation, Jan. 29, 1918.—Horseshoe incision on inner aspect of knee-joint. Internal lateral ligament exposed. Sartorius divided at upper margin of wound, and upper end of lower portion stitched to periosteum of internal condyle, being tightened as much as possible in the process. A strip of fascia lata 3 in. by 1½ in. taken from outer side of thigh was sutured to inner portion of joint superficially to the sartorius tendon, and stitched above and below to periosteum of femur and tibia respectively. Wound closed without drainage. Leg immobilized for four weeks.

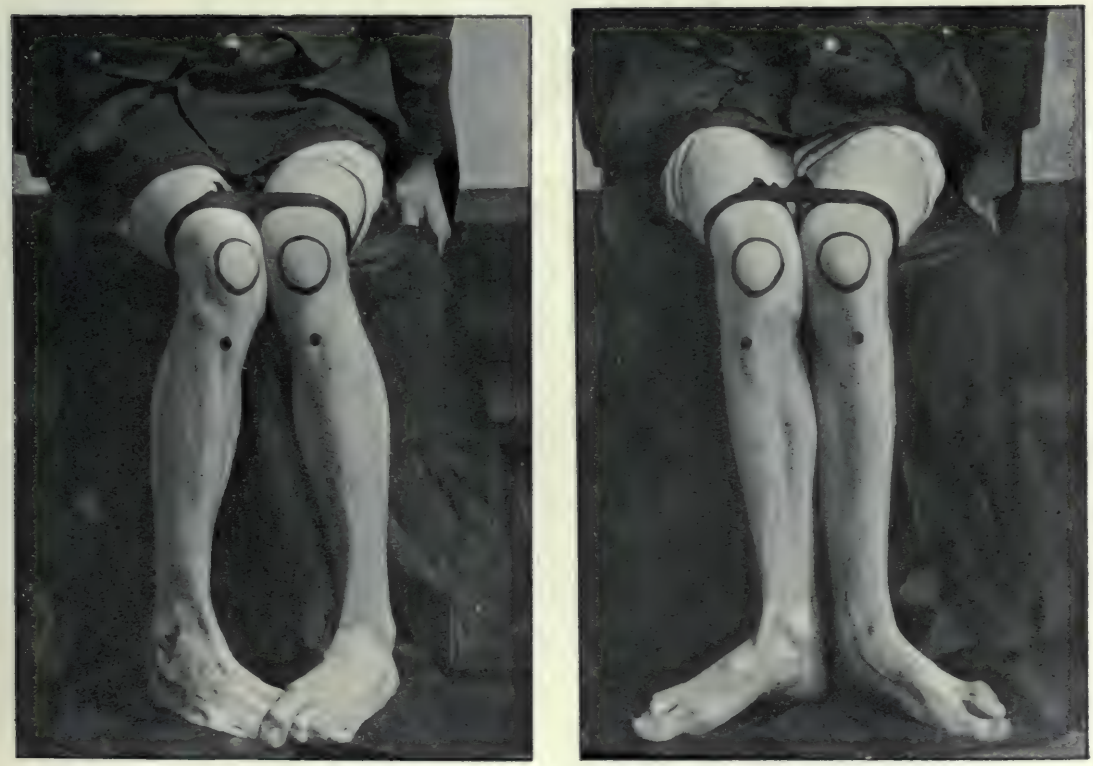
After eight weeks the lateral mobility was markedly improved—the new ligament appearing quite firm. Knee was still painful if a mis-step was taken, but patient could walk well, and derived great benefit from the operation. Sent to duty at home.

Case 7.—**Anterior crucial laxity with tearing of the internal semilunar cartilage. Treated by fascial ligament and sartorius fixation.**

Lieut. C. Injured right knee by falling into a trench, February, 1917. Was at once removed to a dressing station, where it was found he could neither flex nor extend the leg, nor allow it to be manipulated on account of the extreme pain. Marked swelling in knee from onset of injury. Leg was fully extended and fixed in a back splint, and he was sent down the line and arrived in England a few days later. Remained in a London hospital three weeks, and was then sent to a convalescent home. Here he was given massage, which produced pain, and swelling in joint. After a month's treatment he was boarded and marked for G.S. in one month. While home on leave, knee began slipping, as he was walking more than he had hitherto been able. A definite locking followed a mis-step, and the leg 'let him down.' Following this locking, all the old symptoms returned. He reported at the nearest military hospital, where he was admitted and put to bed, with counter-irritation to reduce the synovitis. After six weeks was transferred to special hospital where the internal semilunar cartilage was removed. Two months' after-treatment, during which time no further lockings occurred, but knee was more unstable



FIGS. 161, 162.—*Case* 7. Showing antero-posterior 'rocking' movement of tibia on femur.



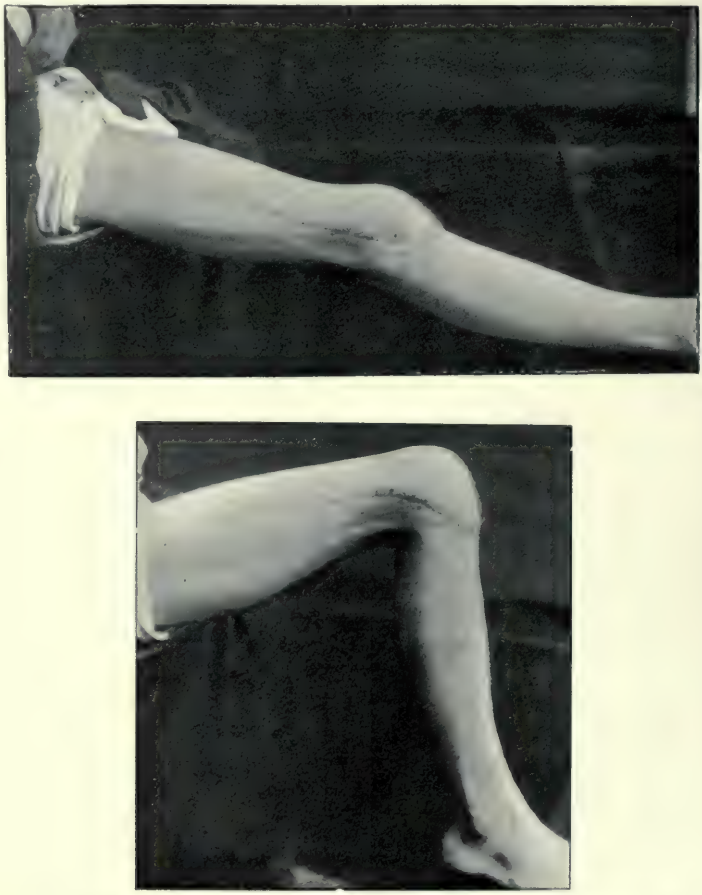
FIGS. 163, 164.—*Case* 7. Showing increase in inward and outward rotation of tibia.

than before the operation, and appeared to continue slipping, although this was not painful as before.

On admission July, 1917.—Knee-joint was very mobile and at will the tibia could be pushed forwards on the femur, causing a definite slip or 'rocking' movement (*Figs.* 161, 162). Rotation inwards increased, rotation outwards markedly increased (*Figs.* 163, 164). Treatment by internal crooking of sole and heel and a cage splint instituted, combined with massage and faradism of quadriceps. No improvement followed, and joint continued to display the most alarming mobility as regards lateral and anterior movement combined with rotation in both directions of tibia on femur. Patient was very dissatisfied with his condition, and readily agreed to operative interference.

Operation, February, 1918.—Usual U incision and split-patellar route. Sartorius was divided above level of inner condyle and the upper end of lower portion was stitched to periosteum about the adductor tubercle. Anterior crucial ligament was thinned and atrophic. Fascial ligament constructed.

After-result: Lateral mobility not much improved. Antero-posterior mobility greatly improved, and since the tenacity of quadriceps is increasing by massage and exercises the improvement becomes more obvious. The sartorius fixation is the weak point of this operation (*Figs.* 165, 166).



FIGS. 165, 166.—*Case* 7. After operation for construction of new fascial ligament.

Case 8.—**Torn anterior crucial and loose internal semilunar cartilage. Treated by fascial ligament. Standardized operation.**

Pensioner L. History of having been buried in the trenches by high-explosive shell, December, 1914. A shell burst on the parapet, buried him with his right knee doubled under him—he thinks

in full flexion with rotation inwards of tibia on femur. Knee-joint was locked, very swollen and painful, almost at once. Taken to advanced dressing station, where leg was manipulated and extended, which caused much pain. Arrived in England three days after, and was in hospital until March, 1915. No treatment given for knee condition, but other wounds (shell wounds of left hand) were healed and have since caused no disability. Sent to Command Depôt in March, and became Instructor until February, 1916, when he was discharged from army on account of numerous 'lockings' of knee-joint and general instability of the knee.



FIG. 167.—*Case* 8. After operation for construction of new crucial ligament. Showing stability and weight-bearing capacity of the joint with a partly flexed knee.

On admission, March 8, 1918, as a pensioner.—General complaint is of weakness of right knee that has prevented him from doing any work, though he has tried several times. Knee has locked innumerable times—this can always be reduced by the patient. In addition, knee-joint appears 'wobbly,' 'the bones slipping and rubbing on one another' as the patient puts it. On walking, there is dull aching pain in the internal and posterior aspects of joint. Can flex and extend to normal. There is slight lateral mobility when joint is fully extended, but very marked when joint is flexed to 20 degrees. Tibia can be brought forwards on the femur appreciably, especially with knee in semiflexion.

Operation, March 19.—Usual anterior crucial and internal lateral fascial substitution. Internal semilunar cartilage was found circumferentially torn, and was removed. Anterior crucial ligament apparently non-existent, being markedly atrophied.

Cast removed April 22. Knee decidedly firmer in lateral mobility, and antero-posterior mobility has disappeared. There was 30 degrees of voluntary flexion at once, and patient walked across ward without appreciable limp and without pain (*Fig.* 167).

This pensioner now has a full range of movement. There is no preternatural mobility of the joint. Walks well without limp.

Case 9.—**Stretched anterior crucial with cartilage trouble. Treated by fascial ligament. Standardized operation.**

Cpl. P. On Dec. 10, 1917, at a training camp, while running, he slipped on the ground and fell with his leg doubled up and rotated outwards. About ten minutes later he straightened his leg out, but felt something slip in the joint. Was able to limp back to hut. Joint became swollen immediately, and locked again as soon as he returned to the hut, and again that night while in bed. At this time some one had to straighten his leg, as he could not do it himself. After each locking there was an increase in swelling. After twelve days' treatment by rest and lotions in the lines, was transferred to a military hospital. During this interval he had about fifteen lockings. At hospital, treatment by a back splint was continued until Jan. 15, 1918. Splint was now removed and he was allowed to get about. On Jan. 22 the leg locked again. He was ordered to bed, dressings were applied (no splint), and he remained there until end of February, when he was allowed up wearing elastic bandage. Had one locking between this and March 15, when he was transferred.

On admission, March 15.—Elastic bandage on knee. Pain and tenderness around joint—unable to flex leg beyond a right-angle without considerable pain. Much lateral mobility and external rotation of leg. Tibia can be moved forwards on femur, suggestive of a stretched anterior crucial.

Operation, March 22.—Usual crucial and internal lateral ligament operation, with removal of internal semilunar cartilage, which was found torn circumferentially. Immobilization for five weeks, after which movements were begun. Is now walking well.

AFFECTIONS OF THE LARGE JOINTS DUE TO GUNSHOT WOUNDS: THEIR LATE RESULTS AND TREATMENT.

By S. W. DAW, Leeds.

Interference with the functions of joints by gunshot wounds may be manifested in several ways. Among the most important are: (1) *Limitation or absence of range of movement;* (2) *Undue mobility;* (3) *Alterations of the axis of movement.* The disabilities connected with reduction of power to move an otherwise healthy joint belong chiefly to the realm of muscle and nerve surgery, and are outside the scope of this article.

1. **Limitation or Absence of Normal Range of Movement.**—The factors to be considered are, first, the immediate effects of the wound; and secondly, the subsequent effects from suppuration and adhesions.

a. The missile may enter or pass through the joint, smashing or injuring the articular surfaces, or may without immediate damage set up a process of suppuration leading to a secondary destruction of the articular cartilage.

b. There may be a partial or complete fracture near the joint, leading to a mechanical bony block to movement from imperfect reduction of the fracture, displacement of a fragment of bone, excessive callus, or traumatic myositis ossificans.

c. Soft parts only, such as synovial membrane, capsule, ligaments, tendons, muscle, or skin, may be wounded, and, from immediate destruction, suppuration, and final healing by granulation, lead to adhesions or contractures having a pronounced effect in limiting the normal joint movements. The actual site of contracture or adhesion may be over the joint, or at some distance from it, as in the case of adhesions of soft parts to the shaft of a bone.

d. Reflex muscle spasm as a guard against painful movement of an unhealed or imperfectly cicatrized deep wound may of itself cause limitation of movement.

Diagnosis.—An exact diagnosis should always be aimed at, though it may not always be possible to hit the target. A routine treatment by massage and passive movements is to be deprecated, both in the interests of the patient and of science. Much time may be wasted and valuable chances lost if this empirical method is adopted. It is necessary, first, to learn as far as possible what are the difficulties to be met, and next, to decide what is the best way in which they may be overcome.

Diagnosis is made by inspection, palpation, and *x* rays. Inspection may at once reveal an obvious source of trouble. For example, a scar in the flexure of a joint, as at the front of the elbow, may cause no interference with flexion, but when extension is attempted there will be a drag on the scar which will prevent full movement in that direction. In other cases the nature of a deformity or the position of a scar may point directly to the cause of limitation.

Gentle attempts at passive movement will yield valuable information. The joint may be without movement; but, whereas in the presence of bony ankylosis the rigidity will be absolute and unyielding, in the case of fibrous ankylosis there will be a slight springy recoil accompanied by pain in all attempted passive movements, which will serve to distinguish it from the former condition.

Where movements are merely limited, there may be a sudden and complete stop to movements in one direction, while other movements are more or less free, pointing to the presence of a bony block at one point standing in the way of further movement, or an adhesion on the opposite aspect of the joint acting as a drag or brake to movement. The position of the wound will then help to a decision, as well as the nature of the resistance, whether absolute or elastic.

Where the limitation is not confined to one movement, it is often difficult to make an exact diagnosis. If, however, any one or more movements of the joint are *free*, it is probable that there is no serious intra-articular lesion, as such movements would be impossible in the presence of a definite arthritis. An example from civil practice will illustrate this point. In a case of suspected 'hip disease,' the presence of a full range of rotation will be a point against the diagnosis of tuberculous arthritis, and will indicate some cause outside the joint for any limitation of flexion or extension which may be present. Limitation of every movement is to be considered as a sign of arthritis or of a serious lesion of the joint.

The stiffness from muscular spasm is of a different character from that already described. The resistance is more gradual, and is accompanied by visible muscular contractions and a complaint of pain, without a point of definite stoppage being reached.

X-ray examination is desirable in all cases, and essential in those which are of a doubtful nature. Bony ankylosis is usually unmistakable: the joint cavity is obliterated, and bone in continuity is seen bridging the joint region. Cases of arthritis with complete or partial fibrous ankylosis may show a general cloudiness of outline, a definite irregularity at one or more points in the shadows of the ends of the bones, or in some cases merely a narrowing of the space between the ends of the bones, due to thinning or destruction of the cartilages of the type of plastic arthritis. It is most important and necessary in difficult cases to have a control skiagram of the corresponding healthy joint of the opposite side. Bony block nearly always occurs on the flexor aspect of joints, and is seen as a well-defined shadow near the joint, while the latter appears normal. It is important to remember that in a profile view of a joint an abnormal bony mass may appear to block movement, whereas it is really at one side and may thus cause no obstruction. If careful examination of the skiagram in comparison with that of the healthy opposite joint reveals no change, it must be considered for purposes of treatment that the lesion is outside the joint proper, or is at least of such a kind as is likely to yield to treatment.

2. **Undue Mobility.**—This condition is seen chiefly in the upper limb, notably in the shoulder- and elbow-joints. As a sequel of gunshot wounds, it is usually the result of excision of the joint in question at an early date after the infliction of the wound. A smashing wound of the joint has occurred, and the surgeon removes as far as possible all chance of a spreading infection by making a clean sweep of the damaged tissues. In observing these cases at a later stage, it is impossible to offer criticism of the method employed, as what seems to be a poor result may possibly represent a life or limb saved. It should, however, be clearly understood that these early and extensive excisions lead to extremely bad functional results. There is a wide gap separating the bones which should form the joint, the fulcrum action of the joint is gone, and very little active movement is possible. There is in fact a pronounced form of flail joint. In the case of the shoulder the arm hangs by the side, and only small degrees of flexion, extension, and abduction are possible to the patient. In the similar case of the elbow, the forearm and hand dangle from the elbow, usually without power of active movement. With wide excision of the wrist, the result is even worse: the hand is displaced forward, with deformity of the 'Madelung' type, the carpus being drawn upwards in front of the forearm bones; the alinement of the flexor and extensor tendons of the hand is wrong; and the fingers are held nearly straight and are entirely useless. Moreover, in none of these instances is there any tendency to natural recovery. There is very little bracing action of the muscles and tendons crossing the excised joint, and the weight of the useless portion of the limb below the excision tends to stretch the soft parts still further. In the case of joints which are stiff, time and natural processes may help to effect improvement; but these flail joints will usually remain useless unless treated on the lines presently to be indicated.

3. **Alterations of the Axis of Movement.**—These are of the greater importance in the lower limb, where the function of weight-bearing has to be considered, and especially in the knee and ankle, which act as hinge joints. Mal-union of fractures of the femur

may interfere with the normal transverse axis of the knee-joint in the direction either of genu varum or valgum. The former is usually of an innocuous degree; but the latter, by increasing the normal angle between the long axes of the femur and tibia, not only imposes extra strain on the internal lateral ligament of the knee, but also puts extra strain on the mediotarsal joint, and induces a condition of flat-foot. Malunion of the tibia, when it throws the weight to the inner side, alters the normal axis of the ankle-joint, and so puts strain on the mediotarsal joint, also producing flat-foot.

Manipulation of Joints.—This term is here applied to a procedure by the surgeon to improve the condition of a joint by moving it through a part or all of its range under general anæsthesia.

Before it is undertaken, two considerations must be weighed: (1) *What harm may result;* (2) *What good may result.*

1. The possible objections to manipulation are: (*a*) Lighting up of suppuration; (*b*) Possibility of fracture; (*c*) Liability to increase the disability rather than to reduce it.

As regards *suppuration*, it should be borne in mind that practically every case of a stiff joint from a gunshot wound has been the subject of suppuration. It is therefore generally essential that all wounds should be soundly healed for several months before manipulation is undertaken. The risk of recrudescence is not then absent, but is lessened enough to make the procedure justifiable. In rare instances where a joint threatens to become ankylosed in a bad position, it may be deemed necessary even in the presence of unhealed wounds to move the joint cautiously and gently into a better position, but this should never be done where there is any strong resistance to be overcome—that is to say, when adhesions have already formed. For general purposes, the standard of three months' freedom from suppuration must be adhered to.

The danger of *fracture* is small if proper precautions are used. These are: (i) The application of steady continuous pressure in the required direction, as opposed to jerky muscular efforts; (ii) The light application of metal gutter splints along the whole length of the bones above and below the joint to be moved. It should be the aim of the operator to make a restrained use of an excessive force—as, for example, by bearing the weight of his trunk transmitted through his arms along the whole line of the bone below the stiff joint—rather than to attempt to obtain the required movement by putting forth all the strength of his arm muscles. If the force is applied as described, it is easy to stop at any moment, as it is well under control. The portion of the limb above the joint should be laid flat on a sandbag on the operating table, to obtain steadiness and to let the stress be borne by the whole length of the bone. The use of the gutter splints is a valuable additional safeguard, and is especially needed when there has been a previous fracture of one of the bones involved.

The danger of *increase of the stiffness* by manipulation will depend on the judgement in selecting the case and on the method used. It is now generally admitted that no amount of to-and-fro movement will make rough surfaces smooth, or convert damaged joint surfaces into sound ones. Quite the reverse is the case. The breaking down of adhesions between the cartilages will leave raw, bleeding surfaces. The trauma of the violent movements will increase hæmorrhagic or inflammatory effusion within the joint. The resultant pain will call for prolonged rest, during which time the adhesion of the cartilages will become stronger than ever. If pain and effusion are ignored, and frequent passive movements under anæsthesia are persisted in, the inflammation will be kept up, and the period of rest, which is merely put off, will again lead to resumption of the stiffness. The idea of mobilizing a joint which has been the seat of arthritis in this way must therefore be abandoned as almost certain to do harm rather than good.

2. To turn to the other aspect of the case, the possibilities of doing good by manipulation must be considered. As has been stated, the prospects in the case of arthritis are limited, but at the same time they are very well defined.

Firstly, manipulation may here be used to correct a deformity and to put a joint into a more useful position. For instance, an arthritic knee may have a small range of movement round about 140 degrees. In this position it is comparatively useless.

The knee may be fully straightened by manipulation. If the joint is then quite stiff, the limb is much more useful than before. It may be found, however, that in the course of use a small range of movement from full extension will develop, and give a good walking leg as a result.

Secondly, even in the case of arthritis, judicious manipulation may lead to an increased range of movement. The destruction of cartilage may be limited to one part of the joint, which will usually be fixed in a faulty position from the point of view of function. If the joint is then moved into a position as remote as possible from its former one, each damaged portion will now lie in contact with healthy cartilage. The joint is kept at rest in its new position until all reaction has subsided. The fresh adhesions which have formed will be of a much less serious character than those originally present, and future gradual change of position may now result in quite a useful range of movement. Even in more general arthritis of a joint, manipulation may prove useful if one is content with a small degree of movement, followed by a period of rest until pain and swelling are absent, when the process may be repeated. Much may sometimes be gained by cautious movement of this kind, where drastic measures would do more harm than good. It will be seen, therefore, that in cases of this sort an effort must be made to reduce trauma to a minimum. This is done by abstaining from going too far at once, and by avoidance of all to-and-fro movements, with rest for the joint while any inflammation is present. In the case of the elbow- or knee-joint, the Turner splint (*Fig.* 168) may take the place of such manipulation, or be used to supplement it. This splint consists of portions to be attached to the limb above and below the joint, with an intermediate screw adjustment over the joint. It is fixed to the limb above and below by incorporation in independent sets of plaster-of-Paris bandages over a layer of cotton-wool. The screw may be adjusted to flex or extend the joint, a small change being made daily.



FIG. 168.—The Turner splint.

In connection with either method, voluntary active movements may be encouraged when they become possible; but what has already been said will make it clear that passive movements are worse than useless in an attempt to increase the range of the joint.

When we turn to the consideration of stiffness of an extra-articular origin, a more hopeful prospect of manipulative treatment comes into view. The stiffness in such cases may be due to adhesions or contractions of synovial membrane, capsule, ligaments, tendons, or muscles, to contractions of extensive skin scars, or to bony blocks of the kind already referred to. The last two conditions require special treatment, to be referred to later. The others lend themselves to manipulation for the breaking down of adhesions, with the hope of obtaining a good range of movement. The dangers of fresh suppuration or of fracture must be avoided by the precautions already referred to.

The force is applied as described above; but unless resistance is very great, the joint should be carried through its full range of movements at once. Here, again, inflammatory reaction must be reduced as far as possible, and each movement should therefore be carried out once only. Nothing is gained by repeating the movements.

The after-treatment varies somewhat according to the severity of the case. If the resistance appears to be light by previous examination, gas anæsthesia may be used. As the patient regains consciousness, he is told to put the joint through its movements.

This will give him confidence and assist in future treatment. Judicious passive movements are of great value in such cases. On the following day the joint is put once only through its full range. On the next day, again, its condition is noted. If the pain is less, active and passive movements are proceeded with. If the pain is greater and movement less, it is a sign that longer rest is needed. Further passive movements must be deferred until inflammation has subsided, as shown by the reduction of pain. Gentle stroking massage will be valuable in getting rid of inflammatory swelling.

In the case of more serious adhesions, such as are usually present in gunshot injuries, ether anæsthesia is advisable, so as to give more complete muscular relaxation and to allow more time for the manipulations. The inflammatory reaction is greater, and early passive movements are thereby often contra-indicated. The joint is to be kept at rest, usually in a position remote from that present before the joint was moved, and further movement is started cautiously. The case of the elbow-joint may be taken as an example. Stiffness is usual at about 120 degrees. The joint is put through its full range, and is then slung at rest in as full flexion as possible having regard to the circulation, say about 40 degrees. On the following day passive movement is gently tried. If it is painful, the joint is kept at rest in flexion for about a week. The sling is then relaxed to allow a small range of active movement from full flexion. If this range of active movement is maintained, after a day or two the sling is relaxed a little more, and so on. If, however, active movement becomes less, it is a sign of the need of further rest, and the joint is returned to rest in full flexion for another week, when the process of gradual letting down is again started. In somewhat less severe cases it may be possible to change the position from full flexion to full extension daily with gradually decreasing pain.

The indications for movement in after-treatment may be summarized thus :—

Passive movements are of little use, and may be very harmful in the presence of intra-articular lesions. When the lesion is outside the joint, they are of little use in increasing the range of a joint, but are most valuable in keeping up a range of movement already gained by manipulation. They should never do more than put the joint once through its full range, as nothing is gained by repeating the movements, and inflammatory reaction is thereby increased.

Active movements performed by the patient are nearly always of value, and can rarely do harm in the class of cases under discussion. They should not be used during a stage of obvious inflammation following manipulation, but as soon as inflammation has subsided and pain is gone, or much reduced, they can do nothing but good. At a later stage, the use of a partially stiff joint in a gymnasium, curative workshop, or civil employment, will often lead in the end to a better result than can be quickly obtained by any of the surgical means at our disposal.

Scars Limiting Movement of Joints.—These occur chiefly in the flexures of joints, especially the front of the elbow and the back of the knee. It may be possible to straighten the limb with or without general anæsthesia, and to keep it straight on a splint. If the latter is removed in a short time, the contraction will reappear, and no active power of straightening will be retained. To prevent this recurrence it is necessary to keep the scar on the stretch for a long time, perhaps three to six months. Contraction of scar tissue does not go on indefinitely, and if the stretching is maintained, surrounding skin will be drawn upon in course of time and adapt itself to its new position, after which there will be no further tendency to recurrence. It is important not to add to the amount of scar tissue in straightening the limb, so that in cases of great resistance it is better to extend gradually than to attempt to do too much at once. In such circumstances the Turner splint already described will be of great use. When straightening is complete, it is maintained by the use of a back splint for, say, three months. The splinting is then omitted for gradually increasing intervals, so long as the full range gained can be kept up by voluntary movements. Any reduction of the range is a sign that equilibrium of the scar has not yet been reached, and that a further period of full constant extension is necessary. In suit-

able cases much time may be saved by complete excision of the scar both of the skin and the underlying region. A plastic flap may be brought from one side of the wound to cover the raw space, or, in the case of the elbow, a generous flap may be turned up from the abdominal wall and stitched over the gap. The pedicle remains attached to the abdomen for a few weeks until the flap is well joined and new vessels have been formed, when it is detached by stages to ensure the vitality of the flap. If primary union has been attained, no recurrence of flexion deformity is to be expected, and active and passive movements may be proceeded with at once.

Bony Block.—This is most often found in the bend of the elbow, a piece of bone lying in front of the lower end of the humerus and preventing flexion. It can usually be removed easily by operation. If, as is generally the case, the block is firmly fixed and needs chiselling, a raw bone surface will remain, and it is well to cover this with a flap of deep fascia taken from the thigh. This will take the place of periosteum in preventing the infiltration of muscles with osteoblasts which might lead to new bone formation. The joint is put up in full flexion after the operation, and kept in this position until healing is complete. It is then let down by stages.

Open Operations on Joints.—Those of special importance in connection with the subject under discussion are: (*a*) Excision, to produce a mobile joint or to obtain ankylosis in a good position; (*b*) Arthroplasty, to render a joint mobile; (*c*) Arthrodesis, to obtain fixation of a mobile joint.

In the class of cases under review, *excision* is but rarely indicated. The elbow is the only large joint in which mobility may be obtained with advantage by this method. Here *arthroplasty* may be used as an alternative. This operation will yield a fair range of movement and a strong joint. A well-planned excision at a late stage will produce a better range of movement, but sometimes at a small sacrifice of strength. In the shoulder and wrist better functional results can be got by obtaining stiff joints in a good position than by any attempts at mobilization by excision or arthroplasty. In these joints a linear or wedge-shaped osteotomy near the joint will restore a good position more simply and satisfactorily than an excision.

In the lower limb, stability and weight-bearing are the chief requirements, and operations to mobilize will very seldom improve function. Sometimes a wedge-shaped excision of the knee-joint may be needed to obtain a stiff, strong joint in the straight position. Deformities of the hip or ankle are usually corrected better by a linear or wedge-shaped osteotomy near, but not through, the joint.

Arthrodesis, or joint fixation, may be needed at the shoulder or wrist for flail joints, and also in the former for fixation in some cases of fibrous ankylosis. The adjacent surfaces are made raw, and fixed in position by nails, screws, or wire.

Ankylosis.—Bony ankylosis in a good position is as a rule best left alone. Only in the case of the elbow-joint may mobilization be considered worth while. If the position is bad, correction is to be obtained by one of the means referred to. Fibrous ankylosis will nearly always lend itself to manipulation into a good position. As has been stated, judicious manipulation may sometimes lead to improvement in mobility.

In all cases where ankylosis is inevitable, a faulty attitude must be corrected so that stiffness is maintained in what is the best position for subsequent function. If there is already complete fixation in a bad position, this is to be altered to a good one by one of the methods referred to.

The *shoulder-joint* is in its best position with the humerus abducted about 70 degrees from the side, the scapula being in its normal vertical position. The humerus should also point somewhat forward. The position can be illustrated in the healthy subject by placing the tip of the middle finger over the most prominent point of the opposite clavicle and raising the arm nearly to the horizontal. With a stiff shoulder-joint in this position, play of the scapula will allow the arm to be brought well above the horizontal in one direction and down to the side in the other. It should be emphasized that it is not enough to bring the arm up to this position, but it must come to this point when the scapula is in the normal vertical position.

It is less easy to dogmatize about the best position for a stiff *elbow*. The wishes of the patient should be considered, but an angle of about 100 degrees is most generally useful. The patient is then just able to feed himself and still have a useful reach. Often the question becomes unimportant, as a good movable joint can be obtained by operation.

The rule for the *wrist-joint* is definite. It should be stiff in the dorsiflexed position: function both of flexion and extension of the fingers is then infinitely better than when the wrist is straight or flexed.

The *hip-joint* should be fully extended, slightly abducted, and slightly rotated outward. This equalizes the practical length of the limbs as far as possible, and gives the best stability, standing attitude, and walking gait.

The *knee-joint* should be fully straightened. Slight flexion might be better if it could be maintained, but if this attitude is attempted there is always a well-recognized tendency to the recurrence of flexion deformity.

The *ankle-joint* should be fixed with the foot at right angles to the leg, so that when the patient is standing with his feet together his weight is distributed equally between the heel and the forepart of the foot. Deviation in either direction from this position is equally unsatisfactory.

The *mediotarsal joint* should be slightly inverted, to avoid a tendency to flat-foot.

AFFECTIONS OF INDIVIDUAL JOINTS.

The principles enunciated in the foregoing remarks are those which the writer has made use of in the treatment of joints whose function has been interfered with by gunshot injuries. A brief summary will now be made of the method of their application to the common disabilities found in the large joints of the body.

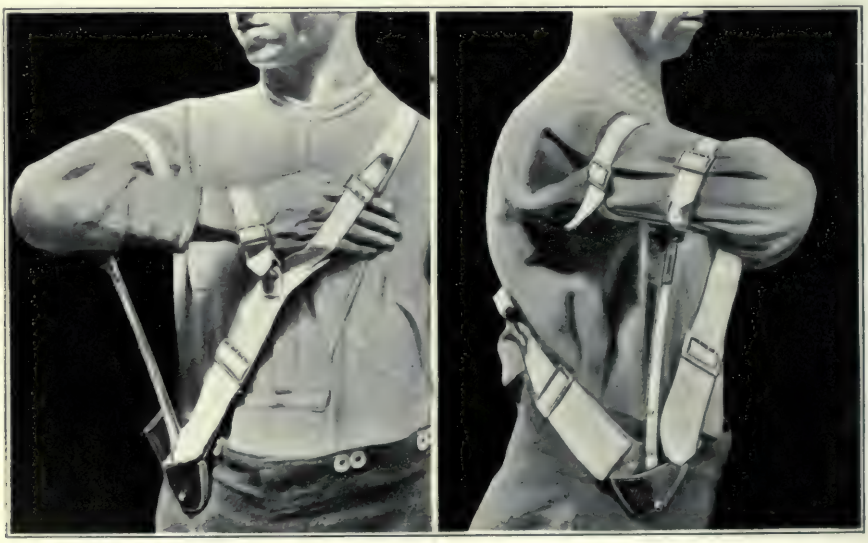


FIG. 169.—Bandolier shoulder-abduction splint.

SHOULDER-JOINT.

Bony Ankylosis.—Adduction deformity is common. This may be regarded as slight if the patient can already raise the arm to the horizontal by scapular movement. With greater degrees of adduction a wedge of bone is excised from the outer aspect of the surgical neck, to bring the humerus out to an angle of 70 degrees from the scapula. The bandolier shoulder-abduction splint (*Fig.* 169) is retained for six weeks

Fibrous Ankylosis.—The above-named position is obtained by manipulation. Over-correction should at first be reached, to allow for sagging, and a right angle between humerus and scapula may be aimed at for the time. The splint will be needed for at least three months. After two months it may be gradually lowered as a guard against recurrence. The play of the scapula will maintain a good angle between it and the humerus. If this angle tends to become reduced below the final aim of 70 degrees, longer support will be needed. If the fibrous ankylosis is too strong to allow of manipulative correction, the operative treatment should not be by cuneiform osteotomy, but by arthrodesis.

Arthritis with Limited Movements.—If the ideal position (70 degrees between humerus and scapula) is included in the range of movements, no treatment is indicated. If not, the case is to be treated as one of fibrous ankylosis.

Extra-articular Adhesions.—Mild cases are treated by manipulation once through a full range, followed by active and passive movements, combined with massage and baths. Axillary scars are excised and the raw surfaces closed by plastic flaps ; or, as an alternative, they may be treated by applying the abduction splint in as open a position as the contracture permits, and then gradually stretching the scar by adjustment of the splint. Many cases with the massive deep-seated adhesions following wounds and suppuration, will not yield readily to manipulation. In these circumstances the best position is reached, and the future treatment is as for fibrous ankylosis.

Flail Joints.—The deltoid muscle is usually stretched and useless. The arm should be placed as high as possible on the abduction splint to relax this muscle to allow of recovery of its tone. The end of the shaft of the humerus should be brought into contact with the glenoid cavity or its remains, to allow shortening of ligaments. If good apposition cannot be thus maintained, it can be brought about by abandoning abduction, and slinging up the humerus in a vertical position by adhesive strapping passed round the tip of the olecranon and over the top of the shoulder, as in treating acromio-clavicular dislocations. By one of these means the deltoid is kept relaxed without intermission for three months. Massage and faradism may be used as far as splinting permits. If these methods fail to bring about a stable joint, arthrodesis should be performed, and the humerus and scapula fixed together at an angle of 70 degrees.

Open Operations to Mobilize the Shoulder-joint.—Excision or arthroplasty is sometimes performed on this joint, but the results are only fairly good, and the subsequent function is rarely equal to that of a strong joint ankylosed in the best position. An effort to obtain the latter is therefore the method of choice.

Elbow-joint.

Bony Ankylosis.—Unless special precautions have been taken, this usually occurs at about 130 degrees. This does not allow the patient to reach his head and neck for dressing or feeding. Excision to obtain mobility is advisable. The bone removed should just include the articular surfaces of the radius and ulna below, and the tips of the epicondyles above. It is advantageous to cut through the humerus obliquely downwards and backwards, so as to avoid a broad surface which might again become ankylosed with the upper ends of the radius and ulna. The limb is put up in full extension on a long gutter-splint for a week, then brought into full flexion, and retained by a neck-to-wrist sling. The sling is slackened little by little so long as good active power is maintained. Massage and faradism may be used as soon as the wound of operation is soundly healed. Passive movements are rarely needed, but active movements within the range permitted by the sling should be encouraged when healing is sound.

Fibrous Ankylosis.—This will be the general result of an arthritis of the joint. The operations of excision or arthroplasty are available in case of need ; but unless the ankylosis seems very firm, the effect of manipulation should be tried, as this joint lends itself to the treatment, and a fair range of movement is often obtained. Since

ankylosis in an approved position is not the only prospect, it is not necessary to stop when this position is reached. If the joint yields easily, it may be possible to reach full flexion at the first attempt. The wrist is slung to the neck with the joint flexed, and kept at rest until any reaction has subsided and pain has disappeared. The sling is slackened little by little as previously described. An ultimate active range of at least a few degrees is to be expected, and if this is round about the right-angled position, the functional result is very fair, and may prove satisfactory for the patient's future needs without the necessity of an open operation to mobilize.

Sometimes the resistance to manipulation is considerable, and it is then not to be pushed too far. A slight movement followed by rest or the use of the Turner splint with screw adjustment, and further small movements at later dates, are indicated. Too much time is not to be wasted in unpromising cases if the patient is prepared to have excision done.

Arthritis with Limited Movements.—If these include an angle of 100 degrees, the result may be thought good enough to leave to time. The use of the Turner splint is likely to be valuable here, and avoids the danger of interference with the range already present.

Extra-articular Obstructions.—Scars in the bend of the elbow, and bony block, are dealt with in the way already described. Slight adhesions are broken down by putting the joint once through its full range, following with active and passive movements as soon as swelling and pain have gone. The plan of slinging in full flexion, and letting down gradually, is applicable in these cases as well as in the more serious cases of gunshot-wound adhesion already referred to.

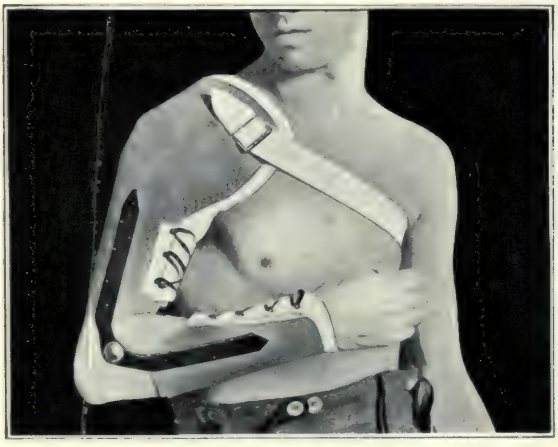


FIG. 170.—Jointed poroplastic splint for a flail elbow.

Limited Extension.—This condition is present in nearly all cases, apart from the question of contracted skin scars already discussed. The disability is comparatively a slight one. Manipulation does not yield good results. The most promising line of treatment is by gradual stretching with the Turner splint. Generally speaking, attention is to be concentrated on obtaining flexion. Time and occupation will often do much to remedy the limitation of extension, and gravity will also act in this direction.

Flail Elbow.—This is the result of too wide an excision. Function is often extremely bad. No stability can be obtained by muscular effort, and the limb is almost useless. An attempt is to be made to obtain contraction of the over-stretched soft parts by slinging the wrist to the neck and applying a figure-of-eight bandage over the joint to draw up the slack. The bandage may be removed daily for massage and faradism, but the wrist sling should never be relaxed, lest all the good be undone. This treatment for three months may lead to decided improvement, and enable the patient to flex the elbow voluntarily. The sling may then be abandoned during periods of activity. Failing improvement, the case may be treated by appliance or operation. A jointed poroplastic splint has been used, with a stop at the elbow preventing extension beyond a right angle, but allowing flexion (*Fig.* 170). This has afforded some relief and allowed of light occupation. Operation may be directed to fixation of the joint at a chosen angle by arthrodesis, or to strengthening the joint by forming new lateral ligaments from portions of fascia lata from the thigh.

Radio-ulnar Joints.

Loss of supination is common in injuries of the forearm, both from fracture and wounds of soft parts. Pronation is the position of rest, and is that naturally assumed during periods of inactivity. Full supination is to be aimed at in treatment. This may be reached by manipulation, and maintained by an interrupted gutter-splint with arm and forearm pieces. The forearm gutter is twisted in the direction of supination, and an anterior gutter similarly twisted is applied, extending from the elbow to the palm. Massage and faradism are used, and the splinting is maintained until equilibrium between pronators and supinators is established, or until the joint is stiff in supination. The natural tendency to pronation will prevent too great a final degree of supination, except in the case of bony ankylosis, when a half-way position must be finally reached.

Wrist-joint.

The disability directly due to stiffness of the wrist-joint is comparatively small if the joint is in an advantageous position, namely, that of full dorsiflexion. This point must be strongly insisted on. Not only does it lead to the best action of the flexors and extensors of the fingers, but the hand is in a better position for manual occupations. It is rarely necessary to be anxious about mobility. The joint is got into full dorsiflexion, and any future possible range of movement can be left to nature. Stiffness has nearly always been reached in the straight or flexed position, and this must be corrected in all cases. Bony ankylosis is met by linear or wedge osteotomy through or near the joint. Other causes of stiffness can be met by manipulation. Resistance is often very great, and will then call for the use of the Thomas wrench with ether anæsthesia. The process may have to be repeated in stages until full dorsiflexion is gained. Some form of the short wrist-splint is used to maintain the position. The palm and forearm portions should be bent to a right angle. The size of the palm portion may at first be necessarily so long as to interfere with the metacarpo-phalangeal flexion movements, and should be shortened by cutting or changing the splint when a good position has been assured. In some cases it is well to incorporate the splint in a plaster casing, as it may be difficult otherwise to maintain the proper position. Massage and exercises should be used for the finger movements during the wearing of the splint, which may be necessary for several months.



Fig. 171.—Morton's wrist splint.

Flail Wrist.—The disability is very great. The hand is displaced forward, and both flexors and extensors of the fingers and wrist are put out of action. Operation for fixation is the only possible procedure. The lower ends of the radius and ulna are exposed and freshened. Holes in the carpus are gouged for their reception, rather toward the back, so as to dorsiflex the hand. Nails are driven in through incisions on the palmar aspect of the carpus, engaging the radius and ulna, and keeping up the dorsiflexed position. The short wrist-splint will be needed for at least three months.

Dorsiflexion and Supination Splint.—Sometimes supination and dorsiflexion are needed at the same time, not only in nerve palsies but in joint injuries. Morton's wrist-splint is most valuable here (*Fig.* 171); supination is maintained by a sling to the

bar which points anatomically forwards from the front of the inner side of the splint; dorsiflexion is provided by the shape of the splint, into which the forearm and hand fit naturally.

Hip-joint.

The chief concern is to obtain a stable joint in a good position. Efforts to mobilize are rarely indicated.

Bony Ankylosis.—There is usually flexion and adduction deformity. This is best corrected by a wedge osteotomy through the lower part of the great trochanter. The patient is fixed on the double Thomas abduction frame for six weeks, after which he may be allowed to walk. It is essential that the position obtained should be one of full extension, slight abduction, and slight eversion.

Fibrous Ankylosis and *Limited Movements from Arthritis.*—These are treated by manipulation into the best position. The joint is maintained in this position, on the abduction frame for six weeks. The patient may then be allowed to walk gradually. Any possible final range of movement is best left to natural improvement in the course of walking exercise.

Extra-articular Adhesions.—If *x* rays show a normal joint, and particularly if some movements of the joint are perfectly free, manipulation may be undertaken in hope of a movable joint, further treatment being on the lines already indicated for other joints. If great resistance is found, or if grating on movement suggests trouble within the joint, rest in abduction and extension will be needed, as in arthritis.

Bony Block.—This may be limiting abduction. It should be either removed or detached, and the limb fixed in full abduction on the abduction frame for several weeks.

Flail Joints.—A destructive wound of the joint may lead to a practical loss of its stability, with telescope action of the thigh on the side of the pelvis. For perhaps a year or more it is advisable to treat this in a palliative manner by applying a Thomas caliper which will enable the patient to walk fairly well. If fixation is desired later, this will be obtained by an open operation to freshen the opposing surfaces and attach the upper end of the femur to the side of the pelvis in slight abduction.

Coxa Vara.—This may occur from mal-union of the neck of the femur. It is treated by cuneiform intertrochanteric osteotomy, followed by rest on the abduction frame until consolidation is complete.

Knee-joint.

Deformities.—Genu valgum and varum are due to mal-union of fractures of the thigh and leg. Their treatment, which is on recognized lines, hardly comes within the scope of this article. Genu retrorsum, or 'back-knee,' needs special mention, as, in addition to the mal-union which is the primary cause, there is a secondary stretching of the posterior ligament of the joint. It is treated by raising the heel of the boot and applying a knee cage (*Fig.* 172) with a stop to prevent full extension. This may be used for a year. If operative treatment is then required, it will consist in a wedge osteotomy at the back of the lower end of the femur, followed by splinting in flexion until union is sound.

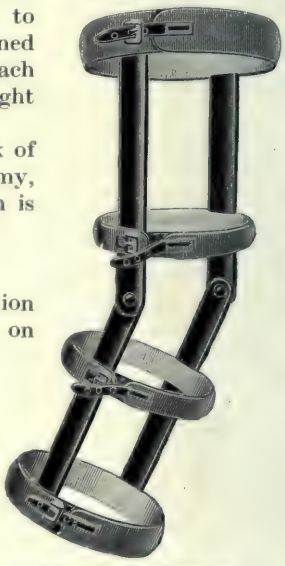


Fig. 172.—The knee cage.

Bony Ankylosis.—Open operations to mobilize a stiff knee-joint have not had very encouraging results. The general aim in ankylosis, therefore, is to restore a good position—viz., that with the limb fully straightened. A wedge-shaped excision is the line of treatment recommended in the rare cases where ankylosis has been allowed to occur in a flexed position.

Fibrous Ankylosis.—This may be so firm that removal of a wedge may be needed,

as in bony ankylosis. Milder forms can be corrected by manipulation. If there is any backward displacement of the tibia on the femur, open division of the hamstrings will usually be advisable. This is done a few weeks before straightening is to be attempted. It should be remembered that the knee is not a true hinge-joint, and if straightening is made without freeing the joint surfaces, the tibia will not roll round to the end of the condyles of the femur, but will pivot on its own anterior edge, which will remain attached too far back on the condyles, causing a posterior displacement. With the patient lying on his face, further flexion of the joint is first made to free the front part of the attachment of the tibia to the femur. Full extension may then be possible with the bones in their normal relationship. If not, flexion must again be made with a well-padded band in the flexure of the knee—the ends of the band being held over the lower end of the table—to act as a fulcrum. By this means the tibia can be made to slide over the condyles, and correct straightening be obtained.

The foregoing remarks apply to cases with powerful and otherwise immovable adhesions. Milder cases may be straightened without great difficulty. Apart from the dangers of suppuration, it is very rarely bad practice to straighten a bent knee, whatever its cause. When it is a question of bending a straight knee, the most careful judgement is required, as this will only be done in the hope of a gain of mobility. In a case of arthritis it can never be useful to bend forcibly. If the arthritis is of so mild a type that some movement is hoped for, this is to be attempted by the use of the Turner knee-splint—resembling the elbow-splint shown in *Fig.* 168—or by allowing the patient to walk, when natural movements will in course of time bring about as much improvement as is practicable.

Extra-articular Adhesions.—These will usually leave a limited range rather than full fixation. Scars at the back limiting extension may in slight cases be treated by manipulation into the straight position; the patient is then allowed to walk in a Thomas caliper for a few weeks, after which active movements are permitted. More severe scars, whether of skin or deep structures, are better treated by gradual stretching. This may be carried out with the Turner splint, a malleable back splint, or a Thomas bed splint, according to the degree of flexion. The larger degrees are put into the Turner splint; intermediate cases have the back splint applied slightly straighter than the limb, and adjusted by stages as the limb conforms to the line of the splint; and small degrees are treated by the Thomas bed splint, with extension from above the knee and bandages across from side to side in front of the thigh and behind the leg. When the limb is straightened by any of these means, the patient is allowed to walk in the Thomas caliper for three months, a back splint being applied during rest. After this time recurrence of deformity is not to be expected, and active exercise and movements are begun, a splint being used at night until full voluntary range is assured. Massage and baths to improve the circulation and loosen scars are valuable adjuncts to treatment during the whole period of correction.

Scars in front limiting flexion are, in war injuries, rarely slight enough to yield to the breaking down of adhesions and free mobilization. The Turner splint is most suitable here. It is put on in full extension, and gradually flexed. When a range of about 45 degrees has been gained, the splint may be abandoned. Massage and active exercises are started, and the patient is allowed to walk. Once a start has thus been made, walking with normal swing of the knee is possible, and the range will gradually increase as fibrous tissue becomes absorbed.

Ankle-joint.

The common deformity is equinus or dropped foot, arising from many causes affecting the joint directly or indirectly. Simple cases from extra-articular lesions may sometimes be corrected by massage and exercises; but the vast majority from all causes are to be treated by immediate correction, with lengthening of the tendo Achillis. Transverse division of the tendon is usually bad in adults, as recovery of strength is retarded. The method of subcutaneous lengthening is completely satisfac-

tory. The tendon is cut half-way through in opposite directions at an interval of about 1½ inches. The foot is then dorsiflexed forcibly, if necessary with the aid of the Thomas wrench, when the intermediate portions of the tendon slide upon each other in the direction of lengthening. The foot is put up in slight over-correction on a shoe splint (*Fig.* 173). Weight-bearing is usually possible in about three weeks. Any tendency to recurrence of deformity is met by a retentive apparatus. The writer has found the ' drop-foot splint ' (*Fig.* 174) quite satisfactory. A short caliper is used, ending above at the upper part of the leg, and below in transverse pins which fit into sockets in the heel of the boot. Flanges fixed to the heel project behind the side bars and allow dorsiflexion while preventing plantar flexion beyond a right angle.

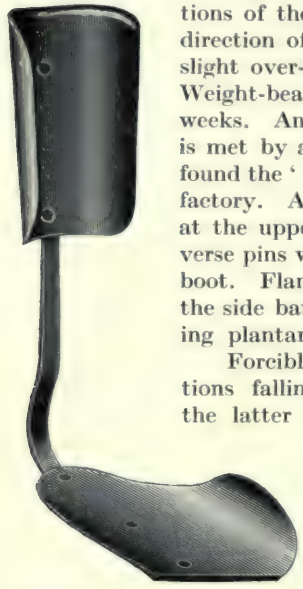


FIG. 173.—Malleable shoe splint.

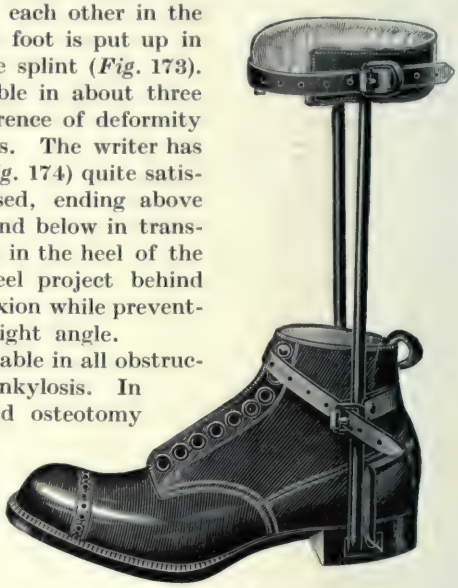


FIG. 174.—Drop-foot shoe splint.

Forcible correction is applicable in all obstructions falling short of bony ankylosis. In the latter case a wedge-shaped osteotomy of the lower end of the tibia and fibula is needed in addition.

The aim, therefore, in deformities of the ankle is to obtain a stable foot. The actual result may be even better, and end in a movable ankle-joint. When this is practicable, it is to be gained by use of the foot in walking after correction has been made.

MEDIOTARSAL JOINT.

Organic deformities of varus or valgus may occur from mal-united fractures and other causes. Their treatment is on the well-recognized lines of that used in civil practice, and needs no special description here.

CONCLUSIONS.

1. Gunshot injuries generally lead to very severe forms of obstruction to the normal movements of joints.

2. Manipulation has its chief use in the correction of deformities, and in changing the position of a joint from one in which function is bad to one in which function is at its best if permanent stiffness is to be the final result.

3. Improvement of mobility is more likely to be gained by slight movements followed by periods of rest, or by slow stretching of contracted parts—in other words, by gradual change of position—rather than by forcible movements through a large range.

4. Open operations to obtain mobility are rarely advantageous except in the case of the elbow-joint, where they are usually satisfactory.

5. Massage and baths are valuable adjuvants to improve circulation and aid in the dispersal of scar tissue.

6. Passive movements have very limited value, and are often harmful.

7. Active movements, especially those of normal use and occupation, are most valuable, and will often do more to increase mobility than any surgical means at our disposal.

UNUNITED FRACTURES, WITH SPECIAL REFERENCE TO GUNSHOT INJURIES AND THE USE OF BONE GRAFTING.

By ERNEST W. HEY GROVES, Bristol.

This paper deals with a series of 60 consecutive cases treated by the author during the last two years, and refers almost entirely to gunshot injuries. From a practical point of view I have thought it better to direct attention to an unselected series of cases, pointing out the difficulties of treatment and the causes of failure, rather than to attempt a literary review of the work of other surgeons. At the present moment the material for the latter attempt is lacking, owing to the fact that only small groups of cases have been published. On considering one's own work, and in discussing the matter with others, one derives the impression that a general feeling of discouragement and failure has prevented publication: but further reflection makes it an obvious duty to enquire into the whole matter, in order that the causes of such failure may be understood, and avoided or overcome in the future.

I. REMARKS ON THE CAUSES, INCIDENTS, AND NATURAL RESULTS OF UNUNITED FRACTURES.

There are certain obvious causes of non-union of fractures, and others which are more obscure, depending upon altered vital conditions of the bone-producing cells which are, at present, matters, of speculation rather than observation. I propose in this paper to deal chiefly with the obvious causes, which could be recognized in all the cases in the present series.

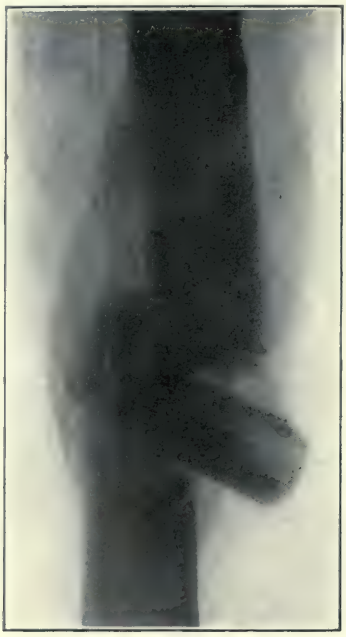
Such causes are four in number, viz.: (1) *Primary loss of substance* (34 cases); (2) *Necrosis or secondary loss of substance* (3 cases); (3) *Displacement, with intervention of soft parts* (21 cases); (4) *Eburnation or sclerosis* (2 cases).

The incidence of these causes in relation to various bones is shown in the following table:—

Bone	Loss of Substance	Necrosis	Displacement	Eburnation	No. of Cases
Radius	10	1	2	—	13
Ulna	8	—	3	1	12
Radius and ulna ..	—	1	—	1	2
Humerus	9	1	3	—	13
Femur	3	—	13	—	16
Tibia	4	—	—	—	4
Total ..	34	3	21	2	60

1. Loss of Substance as the most important Factor in the Production of Non-union of Gunshot Fractures.—This cause is the most important, and accounts for more cases than all the others put together, viz., 34 (56·6 per cent). In the bones—e.g., the radius, ulna, and tibia—where there is another parallel bone which maintains the length of the limb and prevents contraction from bringing about a closure of the gap, the reason for loss of substance leading to non-union is obvious. Whatever may be our conceptions as to osteogenesis, we cannot be blind to the fact, that in the adult a gap in one of the long bones remains unfilled by new bone in a large number of cases. Neither the periosteum nor

the cut ends of the injured bones produce any appreciable callus repair. In fact I would go so far as to say that I have seen no evidence of the reconstruction of the diaphysis of an adult bone when a considerable portion of it has been removed. And this in spite of the fact that I have been looking for such evidence very closely, and asking for it from others. It is impossible to say to what extent the loss of bone is actually occasioned by the original wounding missile, or how far it has been due to primary surgical interference, or to later sepsis ; but there can be no doubt that in a great many cases the bone has been very freely sacrificed by operative attack, as is shown by clean sawn ends, and also by statements on the field cards, such as "Bone fragments freely removed," etc. It would be quite unfair to criticize such treatment without knowing the circumstances which appeared to justify it, and I have no doubt that rapid clean healing has often been promoted thereby, and that limbs and even lives have been saved which would have been lost





FIGS. 175, 176.—Right and left femurs of an officer who fractured both thighs and his skull in a flying accident. The photos are taken four weeks after the accident, and illustrate the rapid formation of callus under the influence of constant movement. The patient was delirious and violent for all this period, and was treated by 20 lb. weight extension applied by tibial transfixion to each leg. He obtained a perfect functional result, and was able to play tennis four months after injury.

by more conservative methods. But it is useless to shut our eyes to the fact that this free removal of bone does almost inevitably lead to an ununited fracture which causes a very prolonged loss of function and which requires a most difficult and uncertain operative treatment for its final restitution.

It must be observed here that the present series of cases does not include any which have recovered apart from definite reconstructive operations, the reason being that one cannot draw the line between many cases of merely delayed union and those which are really cases of non-union. Thus, we have had a large number of cases of fracture the union of which was delayed by sequestra, and in which rapid union took place after the removal of the dead bone. This observation leads to the conclusion that, whilst primary removal of all loose fragments is likely to cause an ununited fracture, if the case is freely drained and properly immobilized, and left until the dead bone is naturally differentiated from the living, before the removal of sequestra, natural union will generally occur.

It is a monstrous misuse of terms and a flagrant begging of the question to call all loose fragments of bone in a comminuted fracture 'sequestra,' and to teach that primary subperiosteal sequestrectomy should be the treatment. I have elsewhere published a sufficiently large series of cases of consecutive gunshot fractures of the femur to demonstrate that the cases of comminution heal with rather greater rapidity than those of a more simple nature, and I have also given experimental evidence to the same effect. The present study of cases in which a large removal of bone fragments has been carried out is the natural complement of the experimental and clinical evidence as to the importance of the bone fragments in bringing about natural repair.

To sum up : Always supposing that free drainage has been secured, with a removal of gross dirt and septic foreign bodies, then the leaving of bone fragments in a comminuted fracture is the surest way of securing natural and rapid repair, whilst removal of these fragments is the surest way of producing an ununited fracture.

I believe that it is extremely rare for a piece of bone to be severed from all vascular supply by trauma, and I use the term loose fragment as implying that a piece of bone is

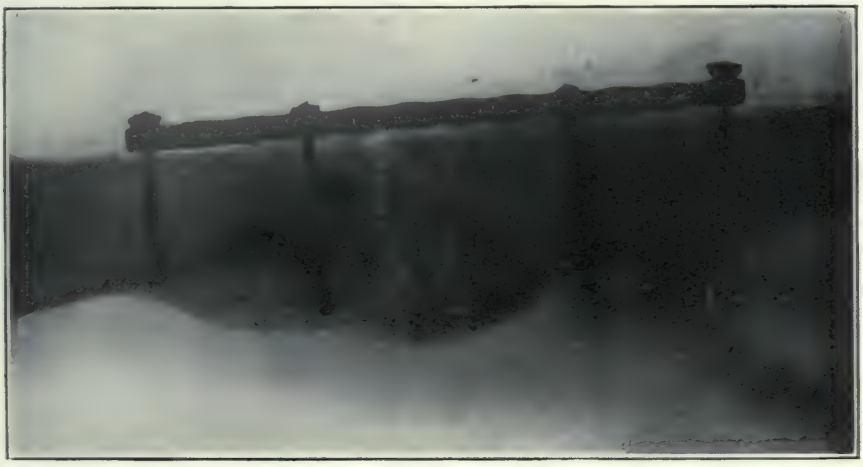


FIG. 177.—Femur of *Case* 47 treated by a bolted plate after seven months' non-union due to displacement. Perfect result, but the plate had to be subsequently removed on account of the formation of an abscess.

separated from the main shaft but not from organically connected soft parts. I have no belief in the value of a piece of bone separated from its blood-supply as an agent of repair, and if such separation is beyond all doubt, then surely the fragment is better away from a septic wound. But it is far better to wait for a few weeks for natural differentiation of dead bone, than to expose and search for sequestra by manipulations which endanger the vascular connections of the fragments in question. Apart from the failure of the wound to heal, there is a ready method of recognizing 'dead bone' in a fracture, and this is usually available in four to six weeks after the receipt of the wound. It is by means of the *x* rays. The region of the injured bone rapidly undergoes changes in density, all the living bone becoming rarefied, whilst the dead bone retains its original opacity.

The radius, ulna, and humerus are the three bones which most often exhibit non-union from loss of substance. In the case of the two former, when the fellow bone is intact, the explanation is that contraction cannot take place. With the humerus, it is the weight of the arm which prevents this contraction, and it is not easy to devise a suitable splint or sling which will obviate this whilst allowing of the daily dressing. One of two devices may be employed, either an abduction arm splint in which the humerus is kept almost in a horizontal plane, or else a special wire cradle splint by which the forearm is slung to the shoulder. The former is suitable for fractures of the upper, and the latter

for those of the middle and lower, portions of the shaft. The tibia is not so frequently the seat of an ununited fracture from loss of substance, because usually the fibula is also broken either primarily or secondarily, and this allows of the apposition of the broken surfaces. In the case of a small gap in the tibia with a large anterior wound which will make grafting difficult, it is better to do an osteotomy of the fibula at an early stage, so as to get the tibial fragments together before sclerosis has occurred. The femur is rarely the seat of an ununited fracture due to a loss of substance, because the strong contraction of the thigh muscles brings the bone ends together, and if the loss is not more than 1½ in., and if care be taken to secure correct alinement, I think that this natural mode of cure should be encouraged.



FIG. 178.—Femur of Lt. T. before operation.



FIG. 179.—Same bone after operation. The large loose fragment was twisted round and had to be replaced. It was bolted to the upper fragment, and this was then fixed to the lower by a clipped plate.

2. **Necrosis.**—This may be regarded as a common cause of delayed union, but a very rare cause of non-union. The present series only contains three cases, and it is worth considering the point whether, in each of these, union would not have resulted from mere sequestrectomy. As it was, in all three cases, as healing had occurred for a long time without union of the fracture, a reconstructive operation was undertaken. As a first step in this, the loose fragments of bone were removed, and it was easy to recognize that they were really dead ; also they lay in purulent fluid. In each case the plastic operation failed to achieve immediate success but ultimate union occurred—i.e., healing by second intention. It is now quite obvious that in these cases, and I think probably in all similar ones, the right method of treatment would have been to be content in the first place with

removal of dead bone and granulation tissue, postponing any reconstructive operation until six months after healing had occurred, by which time nearly all such cases would have undergone spontaneous union. A very important point in this connection is the fact that necrosis very seldom affects the ends of the main fragments of a fracture. If these ends became the seat of necrosis, then this would be a common cause of non-union, because it is from them that natural repair must take place. We often get cases in which the ends of the main fragments have been sawn off, with the idea, no doubt, of removing infected tissue. But as these bones can take care of themselves, and in the process of throwing off infection also throw out reparative callus, it would seem to be a strong

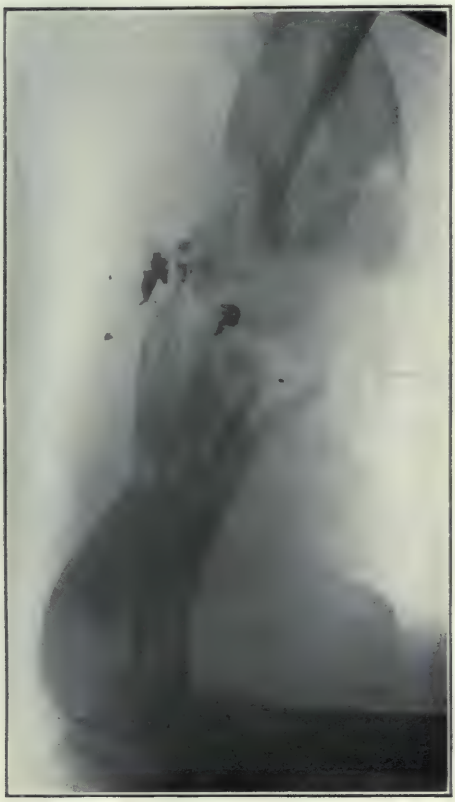


FIG. 180.—Humerus of *Case* 36 before operation. Note the comminution and atrophy of the bone at seat of fracture.



FIG. 181.—The same bone after step-cut operation, fixed between two aluminium bolted plates. Perfect result.

reason for leaving them alone. It seems to me bad surgery to remove any attached fragment from a comminuted fracture ; but it is still worse to cut off the ends of the main fragments.

3. **Gross Displacement as a Cause of Non-union.**—In 35 per cent of the cases, non-union was due to displacement of the main fragments. Such displacement may bring about non-union in a variety of ways—e.g., the interposition of muscle and tendons ; the wrapping round of the raw bone end in periosteum or fascia ; or the placing of a wide interval between the fragments, which becomes filled with dense scar tissue. Non-union of fractures results from displacement, for the same reason that it does from loss of sub-

stance—that is to say, in each case the wounded bone surfaces are removed too far from one another for a callus bridge to occur between them. It is much less likely to result from displacement than from loss of substance, because the most frequent form of displacement is an overlapping, in which broad contact between the fragments is retained. In other words, if alinement is maintained, union will occur, even if there is shortening; but if there is marked angulation, then the bone fragments become separated by the intervention of soft tissues, and callus bridging is prevented.

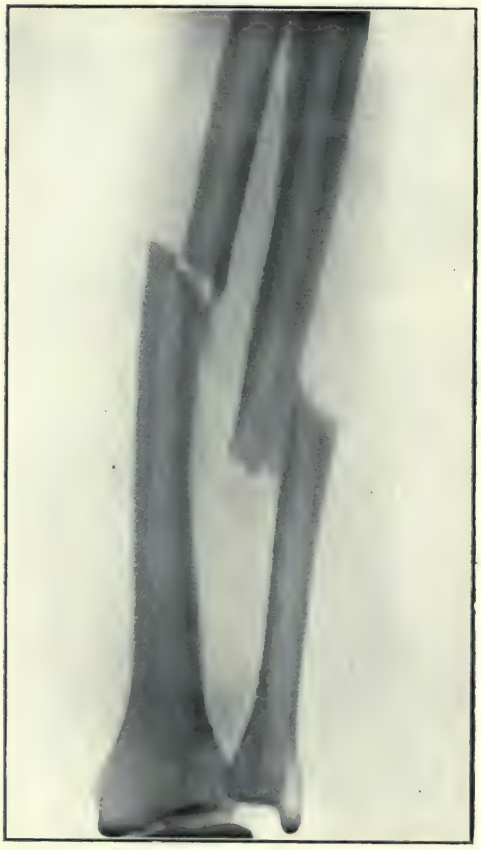


FIG. 182.—Radius and ulna of *Case* 26 before operation.



FIG. 183.—Radius and ulna of *Case* 26 immediately after plating.

The most striking instance of this form of non-union is afforded by the femur, which in the present series, supplies 13 out of 21 cases of non-union due to displacement. Three of these were fractures of the femoral neck, and possibly these should be placed in a category by themselves, because the cause of non-union is rather the primary interposition of the joint capsule than gross displacement. I do not think that any postural or splint treatment will prevent non-union in such cases, and a reconstructive operation should be done as soon as asepsis is secured.

Five were cases of fracture just below the trochanters, and in these the upper fragment was so tilted forward and outward that there was no contact with the shaft. Five

were fractures of the middle of the shaft, in which the lower fragment had sagged backwards with some amount of adduction. One was at the lower end, in which the lower fragment was flexed at the knee so as to lie behind the shaft and at an angle to it. All these varieties of displacement non-union of the shaft of the femur are promoted by the limb having been incorrectly immobilized in the first place. It should be placed in the natural position of muscular relaxation—i.e., with the hip and knee semiflexed and the thigh abducted. In this way can the main fragment best be brought into line with the upper piece which is tilted forwards and outwards, or the lower piece which is tilted backwards. Then, if in this position efficient pin extension be adopted, full length as well as alinement will be attained, and under these conditions I have never seen the occurrence of non-union of the femur.



FIG. 184.—Radius and ulna of *Case* 26 eight months after plating, showing non-union of fracture and pulling out of screws.



FIG. 185.—Same case three months after double step-cut operation.

I might mention, in passing, that this transfixion extension is best carried out in the following manner. The *tibia* is transfixed just behind and below the tubercle by a pin 4 in. long and $\frac{1}{8}$ in. thick. The leg, in the position of flexion of thigh and knee, is then slung either to a Balkan splint, Hodgen, or wire cradle, and extension of about 20 lb. applied. Counter-extension is made by a padded perineal band applied round the sound thigh, and this, by tilting the pelvis up on the sound side, assures abduction of the fractured femur. The great advantage of the tibial site of transfixion is that it concerns dense avascular bone, and not the soft cancellous bone of the lower end of the femur. The pin can be left in place for two or three months, where it remains quite firmly. If the transfixion site becomes a septic seton track, it is so superficial that it is easily treated, and it does not lead into connective-tissue planes like those of the thigh. As the main object of extension of the thigh in fractured femurs is to overcome the contraction of the quadriceps and hamstrings, and as the insertion of these is into the heads of the tibia and fibula, the tibial transfixion site is well calculated to act with maximum result upon these muscles.

I am glad to learn from all published accounts that suspension, weight extension, and the flexed position of the joints have now been generally adopted in the Service; but unfortunately many cases are still put up in the straight position, and merely tied to a splint, and I cannot urge too strongly that this involves a great danger of uncorrected displacement and non-union, especially in fractures of the upper and lower ends of the femur.

Apart from these injuries of the femur, there is one other type of fracture in which displacement commonly leads to non-union, and that is in lesions of the shaft of the radius, where the distal fragment is pulled inwards and is liable to become

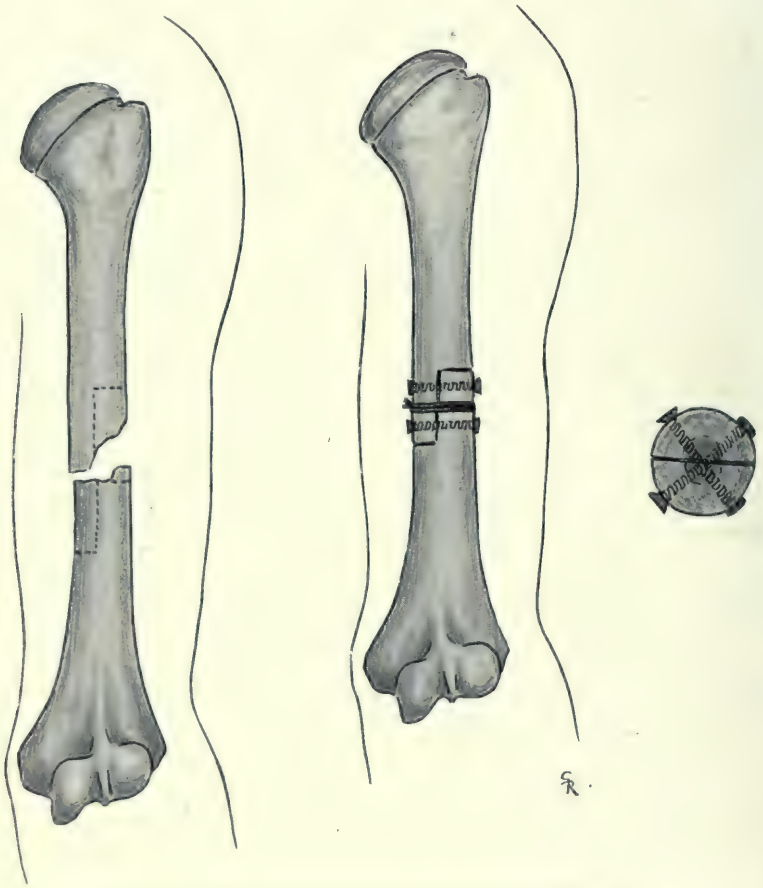


FIG. 186.—Diagram of step-cut operation for ununited humerus.

attached to the shaft of the ulna. Such a case will usually require a reconstructive operation eventually; and whilst primary healing is occurring, all that can be done is to maintain supination of the forearm with adduction of the hand.

4. **Eburnation as a Cause of Non-union.**—The present series contains two instances of this phenomenon. It is so well known as a complication of plating operations that it has been made the basis of the suggestion that all such procedures should be replaced by the sliding-graft operation devised by Albee. I will return to this matter later on in another connection, and in the meantime it is enough to emphasize the fact that operative treatment of fractures may, under certain conditions, be an actual cause of non-union. I have illustrated such a condition experimentally

and the two instances in the present series are also perfectly typical. The ends of the bone are exposed and partly deprived of their vascular supply by separating them from the soft tissues. Then they are fixed to an internal splint, which does not necessarily press the raw surfaces together, but, on the contrary, often holds them apart. The bones, being deprived of the natural stimulus of contact and friction, and having their blood-supply diminished, do not throw out callus in normal amount. Then, when muscular strain is allowed to fall upon the bone, its effect is to loosen the screws in one fragment or the other, and this usually occurs before the delayed callus union has been effected. At this period the bone ends are indolent and eburnated, and non-union is the result. I do not suggest that this is the usual result of plating operations, but it is a sufficiently common one to be a matter of importance. It is likely to occur in proportion to the conditions which favour slowness of callus union. That is to say, it is probable in feeble conditions of vitality and of circulation, in those situations where there is a constant muscular strain tending to angulation, and, above all, when plating is done at a long period after the original injury, when eburnation of the bones has already set in. If I am correct in these statements, then it would follow that plating of the ordinary kind is especially unsuited for the treatment of ununited fractures.



FIG 187.—Diagram of step-cut operation for radius and ulna.

The Influence of Sepsis and Mobility. — It will be noted that I have not included either sepsis or mobility among the causes of non-union of fractures. This is for the reason that, after the most careful consideration, I cannot find evidence of either of these conditions acting in this manner. Of course, a fracture will not unite whilst acute infective inflammation is in progress ; but when this has been checked by drainage and the natural processes of tissue resistance, then the mere persistence of a local sepsis does not cause non-union of the fracture. The more quickly and the more thoroughly sepsis is removed, the quicker and better will be union of the bones. But late union of the bones does occur in the presence of sepsis, and is, indeed, simply a part of the phenomenon of union by granulation tissue.

Neither is mobility of a restricted type a cause of non-union. By restricted, I mean mobility which does not dislocate the ends of the bone from contact with one another. I lately had a remarkable illustration of the way in which mobility actually encourages rapid union. A flying officer sustained a fracture of the base of his skull and a fracture of both femurs. He was put up in two cradle splints with weight extension applied by tibial transfixion ; but for more than four weeks he was very delirious and restless, and in spite of sedatives he moved his legs

incessantly, so that the two weights were pulled up and down on their pulleys with the most menacing regularity. Fortunately his mind made a rapid recovery, and the femurs united firmly in six weeks, whilst he was able to walk in eight weeks, and play tennis in four months. (*Figs.* 175 and 176.) Similarly, I find in all fractured femurs that movements of the knee and hip carried out from the third week onwards, with massage, greatly hasten and assure good union. This can be carried out, when the limb is slung in a semiflexed position and alinement maintained by weight extension, in a way which no other method that I know of allows.



FIG. 188.—Humerus of *Case* 35 before operation.



FIG. 189.—Same bone successfully united by step-cut operation.

One more point may be mentioned in this connection. If an excision of an ankylosed joint is performed, then ultimate mobility—i.e., non-union—will be best secured by absolute rest for several weeks, followed by only the gentlest movements. On the other hand, if anything like forcible (i.e. painful) movements be undertaken at an early stage, then re-ankylosis will probably occur. This is only another illustration of the fact that restricted mobility causes rather than prevents bone growth, whether in the shaft of a bone or at its joint extremities.

The Natural Course of Ununited Fractures.—It is of some importance to inquire what would be the result of leaving ununited fractures to the course of nature. If the ends of the bone are separated by a considerable distance, either from loss

of substance or by displacement, it is almost certain that union will never occur. This for two reasons: first, that new bone is not laid down in adult tissue except as a thin layer covering the bone wounds; and second, that these wounded bone surfaces soon become wrapped round in a dense avascular connective-tissue envelope which seals up the little osteogenic impulse which first existed. It must be admitted, however, that it is extremely difficult to be certain about the behaviour of the bone in any given case, so that it is always wise to wait for a long time before deciding that union is not going to occur by natural means. During this waiting period the various well-known methods of stimulating osteogenesis may be tried. These are—



FIG. 190.—Humerus of *Case* 33 after step-cut operation.



FIG. 191.—Same bone two weeks later, showing the breaking away of the step from the upper fragment. This would have been avoided by the addition of a plate as in *Case* 36, *Fig.* 181.

in their order of usefulness—movement, passive congestion, percussion, and injection of various fluids. In my own experience, the first three of these methods will almost invariably succeed in producing union in all cases where there is actual bone contact between the main fragments, supposing that their application has not been too long delayed. They are quite useless, however, in regard to osteogenesis when there is a large gap between the bone ends, though they do something to preserve vascularity and function.

In all doubtful cases, i.e., where the separation of the bone fragments is definite but small, then decision between expectant and operative treatment must depend upon the amount of deformity which will result from the former, and the prospect of

correcting it by the latter. So long as infection or its results have to be got rid of, and there is definite evidence of recovery of continuity by the bone and of function by the muscles, then the time of waiting is all a gain. On the other hand, if there is no continuity restored in the bone (and this applies especially to single bones, e.g., the humerus or the femur), then prolonged waiting does definite harm. This is due to two circumstances: First, the bone itself undergoes changes which are prejudicial to a reconstructive operation; the fragments always suffer from atrophy or sclerosis, and in each case this involves a diminution both of vascular supply and of bone-forming cells. Secondly, the soft tissues all suffer from the loss of their normal skeletal support; the muscles waste and lose their function, and the nerves are often so dragged upon as to be incapable of conduction. Therefore, whilst I advise waiting where there is prospect of natural recovery, I would deprecate this in other cases where there is great loss of function, deformity, and no prospect of callus union.



FIG. 192.—Humerus of *Case* 34, united over a short ivory peg with successful result.

II. NON-OPERATIVE METHODS OF TREATMENT.

I have already mentioned those means of hastening the union of indolent fractures which are of most service. They are passive congestion, percussion massage, and movements both passive and active. But I do not think that any of these methods are of much avail in genuine cases of non-union—that is to say, in those where the bone ends are separated by dense scar tissue or by soft tissues. Such methods ought to be applied comparatively early in the course of any given case, at a time when cellular proliferation is still a potential factor, and before all bone canals are superficially closed and all intermediate tissue is converted into dense scar. They ought to be regarded rather as methods of prevention of non-union than of cure.

Passive congestion is a method of the greatest possible value in expediting the healing of a fracture. It may be applied in two ways: either by tying a piece of drainage tube above and below the seat of fracture (Thomas); or by the use of a flat rubber bandage applied above the injured portion of the limb (Bier). Each method has its own advantages. Thomas's method produces a more local congestion, but in the forearm and below the knee it has the drawback of tending to displace the parallel bones towards one another. Bier's method produces a more massive congestion, but requires more skill and judgement in its application. It is especially suitable for the forearm or leg bones, and for any case with extensive wounds.

Another method which acts by encouraging local congestion is the application of a light plaster-of-Paris bandage, provided with a window opposite the wound. This should be applied with the limb raised, and when it has set, the limb is lowered and used. Local œdema of the parts at the window is produced, with a temporary increase of discharge. The limb can be used, and this promotes the circulation and also some frictional stimulation of the bone ends.

Deep and percussion massage should be used in all cases where mobility at the

seat of fracture persists unduly. The presence of pain during manipulation is a useful guide in this matter. In the early stages of normal fracture recovery, any attempt to move the bone is accompanied by pain, and such should, in my opinion, be most carefully avoided. Later on, however, if the fracture has assumed an indolent condition, manipulation is painless; and this is an indication that deep massage, and even friction of the bone ends together, should be carried out.

The rôle of *movements* in the treatment of fractures has been emphasized quite rightly by Lucas-Championnière. But movements must be regulated by two conditions: they must be painless, and must not tend to displace the fragments from one another or to alter the alinement of the bone. Passive and active movements, most carefully adjusted for each case, should be carried out as soon as these can be done without causing pain or moving the fragments. Then, when a fair degree of consolidation has occurred, a suitable case splint is applied and purposive functional movements encouraged. I have never seen a case of the non-union of a fracture which could be attributed to such movements, but I have seen many in which delayed union was due to the opposite condition, i.e., to rigid immobility. The great danger of early mobilization of fractures lies in the liability of the bending of soft callus union, and this must be recognized and prevented by suitable splinting or posture.



FIG. 193.—Femur of *Case* 49 successfully united over an ivory peg.

There are four situations in which this danger should always be guarded against: (1) In the upper end of the humerus, the bone becomes angulated outwards, and this can be prevented by keeping the arm in an abduction frame. (2) In the radius, there is always a tendency to pronation, which must be prevented by a supination splint taking its bearing above the elbow-joint. (3) At the upper end of the femur, there is a tendency to angulation outwards, and this often persists in gunshot fractures for twelve months after the original injury. It must be fully corrected in the first place by efficient extension in a position of flexion and abduction of the thigh, and then maintained by some form of rigid metal splint on the outer side of the leg, which is firmly fixed above to the pelvis and below to the condyles of the femur. (4) There is a tendency to a backward sagging of the middle of the femur in fractures of the shaft of that bone. This, again, must be first corrected by suitable cradling combined with extension, and then maintained by a light case splint suitably supported to the opposite shoulder. A rule of safety is to use a walking caliper splint for all gunshot fractures of the femur for six months after union has taken place.

Operative Measures which aim at Callus Production without Suture of the Bone.—There have been many proposals to attempt callus stimulation without bone suture. They consist in needling the bone ends, injection of blood or of fibrin, the insertion of magnesium, or the drilling of the fragments. No doubt all these have a certain value; but from a practical standpoint in dealing with really ununited fractures they are unsatisfactory. Based upon experimental evidence they are liable to fail, for the conditions of an ununited fracture are different from those which obtain in experimental conditions; that is to say, there exists a sclerosis both of the

bone and soft parts in ununited fractures which is not present in animal experiments. Clinically, therefore, these methods either do too much or too little; they are superfluous or they are futile. If sclerosis of the tissues is not present, then the methods of congestion, deep massage, and limited movement will suffice; if it does exist, and if an open operation is necessary, then something more certainly efficacious is indicated. Multiple drilling of the bone fragments after removal of the scar tissue is certainly the best of these callus-stimulating devices; but it will only succeed where there has been no loss of bone substance and no gap to be filled.

III. CONSIDERATIONS PRELIMINARY TO OPERATIVE TREATMENT.

In every case of ununited fracture there is one of three principal causative factors—either a gap in the bone, an interposition of soft parts, or an indolence of the bone ends. The last-named factor is one of great importance, because it arises in every case sooner or later, whether it is a primary condition or not. It may actually arise from the other two conditions—namely, want of continuity or the interposition of soft parts—or it may be caused by septic inflammation, which brings about a filling up of the vascular canals of the bone and a covering of its surface with scar tissue. Indolence of the ends of a fractured bone may take the form either of atrophy or sclerosis. Atrophy is most conspicuous when there is a gap in the continuity of the bone, sclerosis when there has been marked septic inflammation. But in either case the condition of the bone ends with which it is desired to bring about union is very unsatisfactory. Either there is a shaft of a bone which consists of a mere thin shell filled with fatty marrow, or else there is a dense avascular substance which is best described as bone scar tissue. Such bones will not throw out callus in the normal way however they are treated, and all the non-operative methods of treatment are therefore likely to fail. Similarly, other methods which merely aim at suture of the bone, without providing for the removal and replacement of this unhealthy tissue, will also fail, and this must be one of the cardinal facts to be borne in mind in the consideration of all operative procedures.

Before describing and discussing the various operative methods which are available for ununited fractures, it will be necessary to consider various conditions of the tissues which exist, especially in cases of gunshot injury, together with some general technical principles. Upon a correct appreciation of these conditions and principles will depend the choice of cases for operation, the determination of the best period for operation, the selection of the type of operation, and finally, in a large measure the success or failure of the operative treatment. These various factors may be summarized as follows: (1) *Latent sepsis;* (2) *Scar tissue* (skin, soft tissues, bone); (3) *Vascularity;* (4) *Functional conditions of muscles, nerves, and joints;* (5) *Aseptic technique;* (6) *Immobilization.*

1. **Latent Sepsis.**—It would be out of place here to enter into the very difficult problem of septic infections of wounds and the possibilities of their sterilization and suture. But it is necessary to emphasize most strongly certain facts which have been repeatedly urged, and which, though difficult to understand, nevertheless lead to plain conclusions.

Whatever may be the possibility of sterilizing wounds of the soft parts and of the bones in the early stages of their existence, this possibility has vanished at a late period. From this it follows: (1) That the most important problem of military surgery still consists in an early and thorough treatment of the wounds so as to allow of primary or delayed primary suture; and (2) That if this has not been done, then a very long interval must be allowed to elapse before reconstructive operations are undertaken, in order that natural processes of reaction against infective organisms may be complete. We have long been familiar with the idea of latent infection, particularly in the case of tuberculosis. We knew that the so-called cure of a tuberculous disease was often only a comparative term, and that any violent trauma such as that entailed by wrenching a tuberculous joint would almost certainly lead to a violent recrudescence of the infective disease. Just so it is with limbs which have for weeks or months been subject to pyogenic infection. In

proportion, probably, to the length of time that infection is known to have existed, will be the period necessary for the infective agent to be eliminated, even after the outward signs of infection—i.e., inflammation or an unhealed sinus—have disappeared. The probability of latent infection and the length of its duration in any given case is in proportion to: (1) The extent of the primary wound and its degree of infection; (2) The amount of scar tissue deposited in the tissues; (3) The length of time during which manifest infection is known to have been present; (4) The extent of bone involvement. This latent infection will be slight and transient in a clean through-and-through wound which has quickly healed, and it will be great and of long duration in an open lacerated wound which has



FIG. 194.—Femur of *Case* 58, ununited after sixteen months. Note the atrophy of the bones.



FIG. 195.—The same bone united over a long steel strut introduced from the tip of the great trochanter.

slowly healed with a deposit of much scar tissue; and of all wounds, those which have opened up and comminuted large tracts of bone tissue will be those which harbour latent sepsis the longest.

It has been generally accepted that a period of three months should elapse between the healing of a septic wound and the undertaking of any reconstructive operation. This may be a good working rule, but I think should be regarded as a minimum, to be increased when there has been a large wound, much scar tissue, and much bone involvement. I feel it to be especially incumbent upon me to emphasize these points, because I was originally very sceptical about them, and as a result I have had many failures, which duly appear in the present series. I may briefly refer to some of these cases in this connection.

Case 54.—A fracture of the lower end of the femur, in which the distal fragment was tilted backwards almost at right angles. The patient suffered much pain owing to the pressure of this fragment upon the popliteal nerves and vessels. He had two clean granulating wounds, and a febrile temperature. It was three months since the date of his wound. Through two lateral incisions I restored the alinement of the bone, and fixed it by double bolted plates. The operation was very difficult owing to adhesion between the lower bone fragment and the vessels in the ham, the separation of which caused great bleeding. He developed septic moist gangrene of the foot, and after amputation at the fracture had been performed, tetanus supervened, from which he only recovered after a desperate struggle.

Cases 1, 2, 3, 10, 14.—These are examples of cases treated by bone grafting at comparatively short intervals after the healing of the wounds. Failure followed in all, and either another operation will have to be done, or a permanent disability be allowed to remain.

It may be asked why these comparatively early operations were performed. My answer is, that I thought the occurrence of healing was proof of the end of infection, and that by not delaying operation too long there would be a heightened resistance to infection, and the minimum of atrophy of vessels and muscles. But it is evident that such theoretical anticipations are not borne out by the facts; and until some new method of sterilizing the tissues is introduced, the dominating consideration must remain, that every septic case retains latent sepsis long after healing of the wound, and that any attempt to save time by hurrying on a reconstructive operation will defeat its own object: so that by not waiting for three months at first, one may have to wait for a year or more later, before final success can be achieved.

When the wounds have soundly healed, it is not enough to wait passively for three or four or six months; but during this time active and passive congestion must be encouraged by heat, deep massage, and intermittent bandaging with rubber tubes. The functions of the nerves, muscles, and joints must be retained as far as possible by electrical stimulation and, above all, by purposive movements.



FIG. 196.—Femur of *Case* 57 after five months' treatment on a Thomas splint. The upper fragment was tilted forwards and there was neither contact nor union.

2. **Scar Tissue.**—Second only in importance to autogenous infection by latent sepsis as a cause of failure is the presence of large masses of scar tissue on the surface and in the depths of the wound. Probably the infective agents become encapsuled in the scar tissue, just as happens in the healed tuberculous foci of a phthisical lung. Not only is scar tissue resulting from a septic wound to be regarded as a germ envelope, but also it is a tissue of very low resistance to extraneous infection. The most striking evidence of this is afforded by the behaviour of cutaneous scars after operations. The wound heals by first intention, but if a large skin scar has been left to cover the tissues, then, within a few days, this gives way in part, or altogether melts away, leaving a superficial ulcer. But after all, the skin is only the visible aspect of the scar, and the deep scar in the soft tissues and the bone—whether at the ends of the main fragments or as isolated pieces—must also be regarded as tissue of poor vitality, deficient circulation, and weak resistance. The ideal principle to

be arrived at is to remove all this scar tissue before attempting to reconstruct the bone. In practice it is usually the best plan to do one or more preliminary operations for the substitution of the skin cicatrix and the soft-tissue scars. It is best in the case of a large skin wound to take a pedicled flap from the chest (in case of the arm) or from the opposite leg (in case of the lower member), and to cut the pedicle in from seven to ten days. The deep scar is removed at the same time, as far as possible in one mass, the surrounding muscles being then brought together to obliterate the dead space. This secures a thick fatty skin-covering for the site of the future bone operation. It is better to leave the



FIG. 197.—The same bone as *Fig.* 196, united over a long steel tube, which was left in place for eight weeks.



FIG. 198.—The same bone firmly united after removal of the tube.

removal of bone scar—i.e., the ends of the main fragments—until the actual reconstructive operation is to be performed; but loose bits of bone should be taken out with the fibrous scar tissue in the preliminary operation, on the two grounds that they are often the seat of latent infection, and that, being quite indolent and avascular themselves, they only tend to prevent vascularization and bone growth at the site of the reconstructed bone.

3, 4. **The Functional Conditions of the Muscles, Nerves, and Joints, including the Activity of the Circulation.**—It happens only too often that, after a long period of waiting for sinuses to heal and for latent sepsis to disappear, the general nutrition of the limb has suffered and the muscles atrophied to such an extent that a very poor prospect is offered

for bone repair. Under such circumstances it is very doubtful whether it is justifiable to operate, and the question arises whether nutrition and function can be restored before repairing the bone. Two kinds of treatment must be patiently pursued. On the one hand, the nutrition must be maintained and adhesions of the tendons and joints prevented by massage and electrical stimulation; on the other, an apparatus must be provided which enables functional exercise of the muscles to be undertaken, whilst preventing deformity. In principle, such apparatus consists in making a light splint casing for the limb, with joints at the natural articulations; being in reality the provision of a temporary exo-skeleton in place of the missing endo-skeleton. When the muscles have recovered sufficient strength under this treatment to move the limb, and when the blue, cold member has become warm



FIG. 199.—Femur of *Case* 60 three months after accident.



FIG. 200.—Same bone united over a 6-inch by ½-inch ivory peg. The wound healed and the fracture united.

and of a natural colour, then the bone repair may be done with good prospect of success. There is a great temptation to think that the bad nutrition and loss of function is best treated by first restoring the bone; and as I have myself yielded to this temptation, I feel it the more incumbent upon me to state clearly that it should be resisted. In general terms, the longer the period of delay and the greater trouble taken preparatory to reconstruction of the bone, the greater is the chance of success.

5. **Aseptic Technique.**—The general technique of aseptic surgery is so well known as to require no description here. Every proved source of infection and every reasonable suspicion should be guarded against, and this applies especially to the exclusion of the skin from contact with the operator's fingers and the instruments and ligatures. The most

convenient means of carrying this out is by placing the limb in stockingette, the incisions being made through this material, the edges of which are then fastened to the skin by Michel's clips.

There are two procedures commonly recommended for bone surgery which appear to me to have no sufficient justification, but to be open to grave drawbacks. One of these is the dependence on forcipressure alone for hæmostasis. I think it is far better to ligate every bleeding point with fine catgut, for there is nothing more prejudicial to healing than the formation of a hæmatoma. The other is the dictum that the gloved fingers should not be put into the wound. If the hands are clothed with rubber and cotton gloves, I see no reason to doubt the sterility of these any more than that of the instruments or swabs. Moreover, complicated joinery cannot be well done without the help of the fingers. Accurate fitting and firm fixation are the two watchwords of operative bone repair, and for these fingers are necessary.

6. **Immobilization.**—The freshly-united bone must be kept without disturbing strain until firm union has occurred. About this there can be no doubt ; the only question which has to be considered is how this immobility is best secured in such a way as to interfere as little as possible with the circulation of the part and attention to the wound. If the bone repair has been done in a solid manner, then the actual fixation will be secured by this. On the other hand, if the parts, whether bone ends or bone grafts, have only been tied with soft ligatures, then reliance must be placed upon plaster-of Paris dressings. The application of these two methods of fixation will become apparent when the special operations have been considered.

IV. OPERATIONS FOR THE TREATMENT OF UNUNITED FRACTURES.

These may be divided into the following categories : (1) *Plating ;* (2) *Step-cut operations ;* (3) *Intramedullary pegs ;* (4) *Special methods ;* (5) *Bone grafting.*

1. **Plating.**—The usual operation of plating a fracture, practised upon a recent closed aseptic case, has certain drawbacks which I have dealt with elsewhere. These are briefly : (*a*) That the screws, holding only by a friction grip, are easily displaced and loosened by rarefication of bone. (*b*) That the screws, being all in one line, afford very inefficient mechanical fixation. (*c*) That if any tendency to displacement of the fracture persists, the plate becomes loosened from one fragment and allows angulation to occur. (*d*) That, in the case of a transverse fracture, a plate does not press the raw bone surfaces together, but on the contrary holds them apart.

All of these objections, which apply to recent clean fractures, are greatly increased in the case of old ununited and unhealthy bones. In the latter, fixation needs to be more secure and lasting, because natural union is so much slower and the rarefied or sclerotic bone affords a worse hold for screws than does a healthy one. To some extent the drawbacks may be overcome by using curved plates fixed by two rows of converging screws, by the use of bolts or pins which transfix the whole thickness of the bone, and by employing special plate clips which will be presently described. But even with these improvements, plating does not bring about close contact of bone surfaces, nor does it stimulate osteogenesis, but rather retards it. In the treatment of ununited fractures, therefore, plating alone must always be regarded as uncertain and unsatisfactory, and it should be reserved for special cases, or merely used as an internal splint for fixing the bone which has been united by some other method When, however, a plate is used for an ununited fracture, it is very important to fix it in such a way that it cannot become loose.

In easily accessible bones, e.g., the humerus, forearm, and tibia, and in the lower end of the femur, much the most efficient method of fixing a plate is by the use of split-pins or bolts and nuts which transfix the whole thickness of the bone. Split-pins $\frac{3}{32}$ or $\frac{1}{8}$ in. thick are cheap, easily obtained, and easily manipulated in a situation—e.g., the forearm—where both sides of the bone are accessible. The bolts I use are $\frac{1}{8}$ in. thick, and made of soft iron, so that the spare end can easily be cut off. In order to overcome the difficulty of pushing the bolt through from the deep side of the bone, I have devised a simple apparatus

whereby a nut is fixed on to the deep end of the bolt and then the latter is fixed by a second nut on the surface of the plate. *Fig.* 177 shows a fractured femur fixed by a bolted plate.

In most of the gunshot fractures in which bolted plates were used, the latter had ultimately to be removed on account of sinus formation ; but in all except one case they had remained in place long enough to secure firm union in a good line The following is a short summary of the nine cases in the present series in which plating was used.

Case 7.—Radius. Gunshot wound. Curved ivory plate fixed by ivory nails. Completely successful. Plate permanently left.

Case 29.— Humerus. Aluminium plate fixed by transfixing bolts to support a step-cut operation. Plate and bolts had to be removed because of suppuration, and the operation was a failure. Suppuration and failure were due to the operation being done only three weeks after the wound had healed

Case 36.—Humerus. Plate bolted on to support a step-cut union. Complete success. Plate and bolts left *in situ* (*Figs.* 180, 181).

Case 37.—Humerus. Plate and bolts to support step-cut operation. Plate removed after three months. Firm bony union. Successful result.

Case 45.—Middle of femur. Bolted plate. Excellent anatomical result. Legs the same length. Plate removed after six months. Great wasting of muscles. Limited movements of knee, and poor function.

Case 47.—Middle of femur. Bolted plate. Rapid recovery. Discharged with excellent function and perfect anatomical position. Six months after discharge developed an abscess in thigh and the plate had to be removed (*Fig.* 177).

Case 50.—Civil case. Man, age 50, with non-union in middle of femur and 4 in. shortening. After preliminary weight extension, the fracture was fixed by double bolted plate. The operation was very difficult, and he died two days later from shock. Post-mortem showed a fatty heart.

Case 51.—Middle of femur. Bolted plate. Sinuses developed before the wound was healed. The unhealthy bone became actually fragmented further at the points where it was transfixed by the bolts. Plate and bolts removed after four months, and union ultimately occurred.



FIG. 201.—Humerus in *Case* 31; the neck of the bone has been lost.

Case 54.—Fracture of the lower end of femur, in which the distal fragment was tilted backwards. Double bolted plates were applied before the wounds were healed. Gangrene of the leg. Amputation. Tetanus. Recovery (*vide supra*).

In considering this list of nine patients, with one death, one amputation, one complete failure, one doubtful success, and only five good results, it must be borne in mind that the cases concerned were selected bad cases. It demonstrates that the mere mechanical fixation of an unhealthy bone to a plate will not secure natural union. I have learned that it is wiser to be content in some cases with less perfect mechanical fixation, in order to simplify the operation and to have less exposure of the soft parts. This can be attained in the case of the femur either by using a curved plate with two rows of screws engaging the shaft in different radii, or by the use of the clips shown in *Fig.* 179. An ordinary stout Lane plate is applied to the outer aspect of the femur with four screws. A clip is then

placed on its upper and lower end, and fixed by two screws to each, these screws entering the bone at right angles to one another. This will prevent either end of the plate from being pulled away from the bone by the tension of the adductor muscles.

2. **The Step-cut Operation.**—In the case of the humerus or both forearm bones, this is the best operation for ununited fracture, provided that there has not been much loss of bone or atrophy of the bone ends. It involves an ultimate shortening of the bone to the extent of about ¾ in. to 1 in.

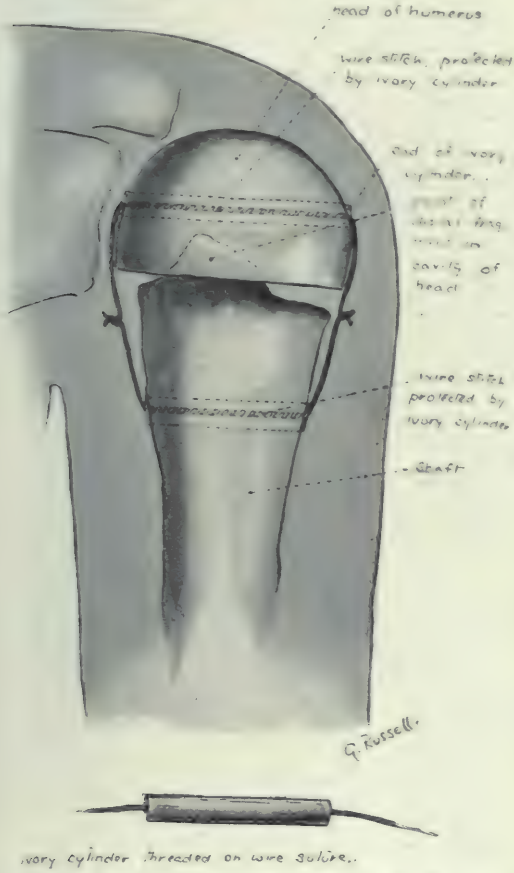


FIG. 202.—Diagram of operation in *Case* 31. The wire sutures are protected from cutting out of the soft bone by being encased in ivory tubes. Successful result.

It is so simple as scarcely to require any description beyond that conveyed by the illustrations (*Figs.* 182 to 188). The bone in question is exposed, all intermediate scar tissue is removed, and the fragments are cut off square. Half the thickness of each fragment is now cut out from opposite sides in the shape of a step about ¾ in. long. The socket in each bone end is then shaped with a square file, so as to fit the other accurately. Having been fitted, the bone is held by a clamp forceps, two ⅛-in. holes are drilled through both flanges in slightly different directions, and the ends are fixed by split-pins or bolts. One case is so instructive in relation to operative bone repair that I will relate it here.

Case 26.—Lieut. C. sustained a simple fracture of both bones of the forearm, March 21, 1917, by falling with his horse (*Fig.* 182). On March 23 both bones were plated in a Devonport hospital, and, as judged by *x* rays and the perfect healing of the wound (*Fig.* 183), it could not have been better done. It was immobilized for six weeks, and then the splints daily taken off for massage for a further six weeks, when recovery was regarded as complete. Slowly, however, the forearm began to bend, until by Nov. 21, eight months after the accident, he had a well-marked false joint, and came to the Bristol Orthopædic Centre for treatment. At this period the *x* rays showed (*Fig.* 184) that each plate had become loose from one bone end, by the pulling out of the screws and loosening of their sockets. A double step-cut operation was done, each bone being united by two bolts. The wound healed well, and by March 3, 1918, his arm had become so strong that he was able to return to ordinary military duty (*Fig.* 185).

It will be noted in this case that though the plates were very perfectly applied within three days of the accident, yet they did not press the raw bone surfaces together, but rather held them apart. Each bone fragment, therefore, healed without throwing out callus. When the splints were removed the bones were only held by plates and screws, and the latter quickly became pulled out from one end of each plate owing to the absorption of their sockets. This is a plain fact to be seen in the skiagram, and not a matter of conjecture. It cannot be attributed to sepsis or faulty technique, because the wound healed well and never showed any sign of irritation. On the other hand, the step-cut operation, by exposing and adapting fresh-cut bone surfaces and then closely pressing these into apposition, conformed to the ordinary principles of the suture of wounds, and resulted in strong natural union.

The step-cut operation is not suitable for leg bones, because it involves a shortening of the limb, which is a matter of only secondary importance in the arm. It is not applicable for one forearm bone the fellow of which is intact. And lastly, it requires for success that the ends of main fragments which are fitted together shall be strong and healthy, subject neither to atrophy nor to that type of sclerosis which really converts the bone into scar tissue. These latter limitations are so important that I will illustrate them by reference to three cases.

Case 27.—An ununited fracture of both radius and ulna, resulting from a gunshot wound. *X* rays showed there were several small bits of bone at the seat of fracture in each case.

Reflection ought to have led to the conclusion that if these bones had been healthy, union would have occurred; but this reflection was made too late. A step-cut operation was done at the same time that the bits of bone were removed, and the consequence was that suppuration occurred. If the fragments had been removed at a preliminary operation, spontaneous union would have probably resulted, and if not, then the step-cut operation done later would have succeeded.

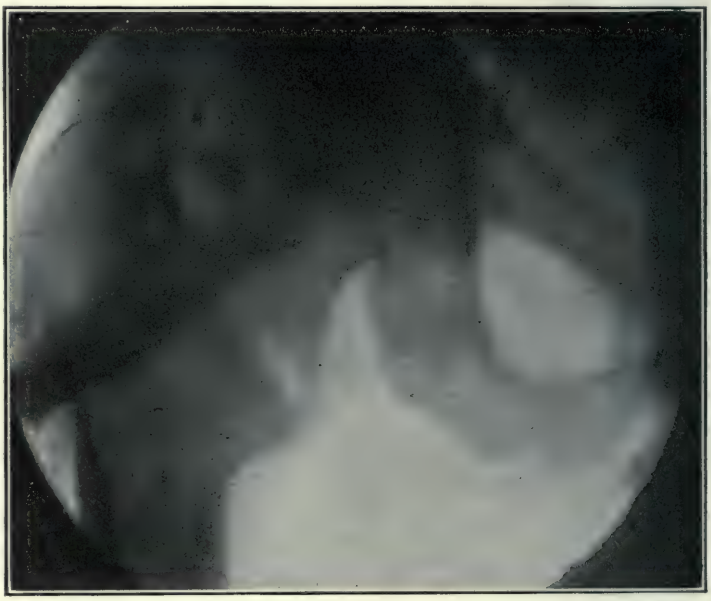


FIG. 203.—Fracture of neck of femur, which had been ununited for five months, now fixed by a tibial bone peg.

Case 33.—A case of ununited humerus with much sepsis and loss of bone, associated with complete musculospiral paralysis. Here no mistake was made in operating too soon; the patient was kept for nearly twelve months, and several preliminary operations were done for the cure of sepsis and the removal of scar tissue. At the operation a tongue of bone was found projecting downwards from the proximal fragment, and this was fitted into the lower part of the shaft and there fixed by two bolts (*Fig.* 190). At first he did well, and was so delighted at the new experience of solidity in his arm that he used it too freely. Re-fracture took place (*Fig.* 191), which is seen to be due to the tongue from the upper fragment having broken off. Disheartened by this, he asked for transfer to a hospital near his home, and I hear that at that institution amputation was performed.

Case 39.—This is almost similar to the above, except that the patient has no musculospiral paralysis, and he is still under my care awaiting further operation.

It is clear from the last two cases that if the integrity and soundness of the bone is in question, it is better to supplement the step-cut operation by a plate which takes off the strain from the actual bone ends. (See *Cases* 36, 37.) In the present series there are nine cases of step-cut operations, six of which have been completely successful.

3. **Intramedullary Pegs.**—*Short Pegs.*—The use of an intramedullary peg has very narrow limitations in the treatment of ununited fractures. It is only of use in the case of a perfectly clean and healthy bone, the fracture of which is recent, transverse, and uncomminuted, the cause of non-union being displacement with interposition of soft parts. The present series contains three such cases—one of the humerus (*Case* 34, *Fig.* 192) and two of the femur (*Cases* 49, 53, *Fig.* 193). In each of these a successful result was obtained, and in view of the ease and simplicity of the operation it is an ideal method.

The pegs I use are turned from ivory or bone. They are $\frac{1}{8}$ to $\frac{1}{2}$ in. thick, and from 1 to 3 in. long. Each has an outstanding ring at its centre, which prevents the peg from slipping down into the cavity of the fragment in which it is first placed. A small incision is required for this operation, merely large enough to allow each fragment to be thrust out of the wound. The marrow cavity of each is opened and drilled until firm bone is reached. The peg is slipped into one fragment, and the other is brought over it by traction and angulation. Such a short peg will not serve to maintain the alinement of the bone, and this must be secured by suitable splinting until union has taken place.

Long Intramedullary Pegs for the Femur, introduced from the Trochanter.—In fractures of the upper end of the femur just below the trochanters, there are two difficulties in treatment. First, the proximal fragment tilts forward and outward, and unless the thigh is kept in abduction and flexion, no amount of traction will secure alinement. Secondly, when this deformity has been established for some time in the presence of sepsis, great atrophy of the upper portion of bone takes place.

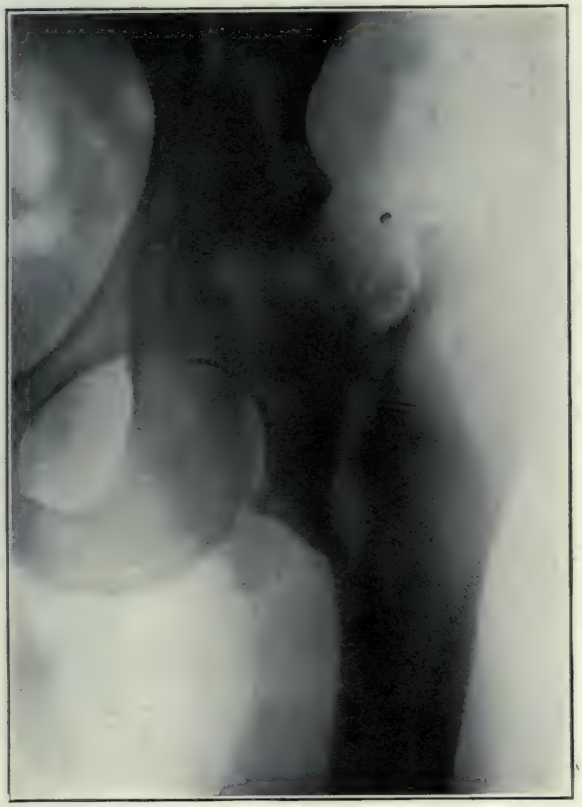


FIG. 204.—The same bone a year later, showing complete absorption of peg, and deposit of dense bone in its place. Perfect result.

In the treatment of such a fracture, whether one associated with non-union or mal-union, not only is considerable force necessary for correction of displacement, but continuous fixation by a powerful appliance of some sort is absolutely necessary in order to prevent recurrence. If this appliance is to be the external variety, it will involve many months in plaster-of-Paris; if it is a plate, then this must be fixed very differently from the manner which is generally employed. In fact, it is the study of any consecutive series of cases of this type treated by the usual Lane plate that affords the most convincing demonstration of the fallacy of the orthodox technique. Plating is nevertheless applicable if a clip or other device be employed to prevent the upper and lower ends of the plate from being separated from the bone. But in that variety of case where sepsis has long held sway and the bone fragments are very atrophic, the extensive exposure and multiple drilling necessary for plating is liable to re-awaken sepsis and to split the friable bone. It occurred to me therefore to use a long internal peg or strut, such as would render unnecessary any further fixation and would afford absolute rigidity. I have used pegs of various shapes, cylindrical, cross-sectioned, and solid rods, and I am inclined to think that the last named are the best, because they give the maximum strength, and there is an avoidance of hollows or crevices which form dead spaces. The technique of its introduction is as follows.

The limb is subjected to transfixion extension for several days before operation. (If the method is used for mal-union and not for non-union, the junction must be divided

by osteotomy before extension is applied.) Then, when overlapping and angulation have been corrected, the operation is performed. The seat of fracture is exposed by an external incision, and each fragment is refreshed and drilled by a ½-in. drill. It will be noticed that after piercing the conical end of the bone, the drill runs into the marrow cavity with the greatest ease, merely displacing a little fatty tissue. After preparing at least three or four inches of the distal fragment, the proximal one is drilled by a special drill 12 in. long. This is driven right up through the great trochanter, the tip of which is exactly in a line

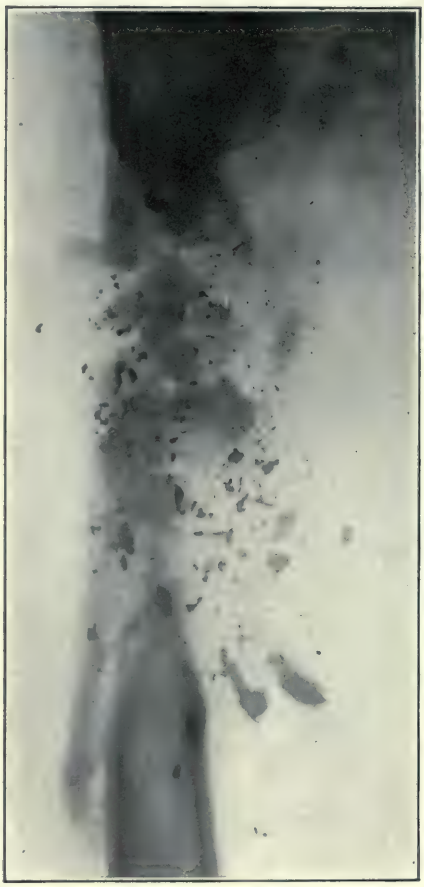


FIG. 205.—Femur from *Case* 55, seven months after injury. There was remarkable comminution, but in spite of the abundant metallic débris there was no sepsis, and the wound of entry was never discovered. There was union of the small fragments with the lower end of the shaft, but non-union between this mass and the proximal fragment, which was tilted forwards.

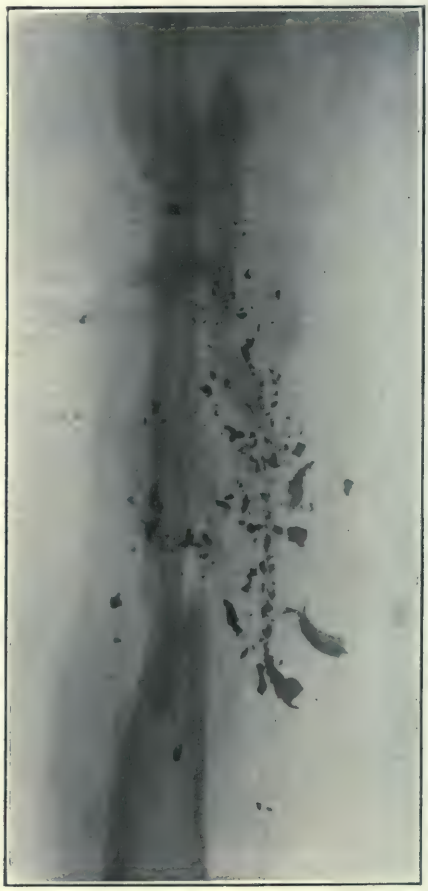


FIG. 206.—The same bone after the use of a long fibula graft. Photo taken one month after operation. Five months later he was able to walk with crutches and work a treadle fret-saw machine.

with the axis of the femur. The tip of the drill is made to emerge against the skin of the buttock, and then cut down upon. The drill is removed, and the peg (6 to 9 in. long) is then pushed up the proximal fragment until its upper end emerges from the buttock wound and its lower is left projecting about half an inch from the bone end. The two fragments are now brought into apposition and into line, and the peg is hammered down until it engages the lower fragment by several inches. The length of the peg ought first to be determined by the position of the fracture, so that when it is in position, with at

least three inches in the distal fragment, its upper end shall remain projecting from the top of the great trochanter. This is to allow for its removal at any time if necessary. The present series contains four instances of the use of this method (*Cases* 57, 58, 59, 60), and it must be admitted that it does not show a very favourable record.

Case 57.—The first case treated by this method, and completely successful (*Figs.* 196, 197, 198). The patient was operated upon in February, 1918, and had the peg removed eight weeks later on account of pain with a rise of temperature. He had then and has now (August) perfectly firm union in good line, and is walking on crutches; but he still has two sinuses, and the case is open to the suggestion that a septic process is still present in the interior of the femur.

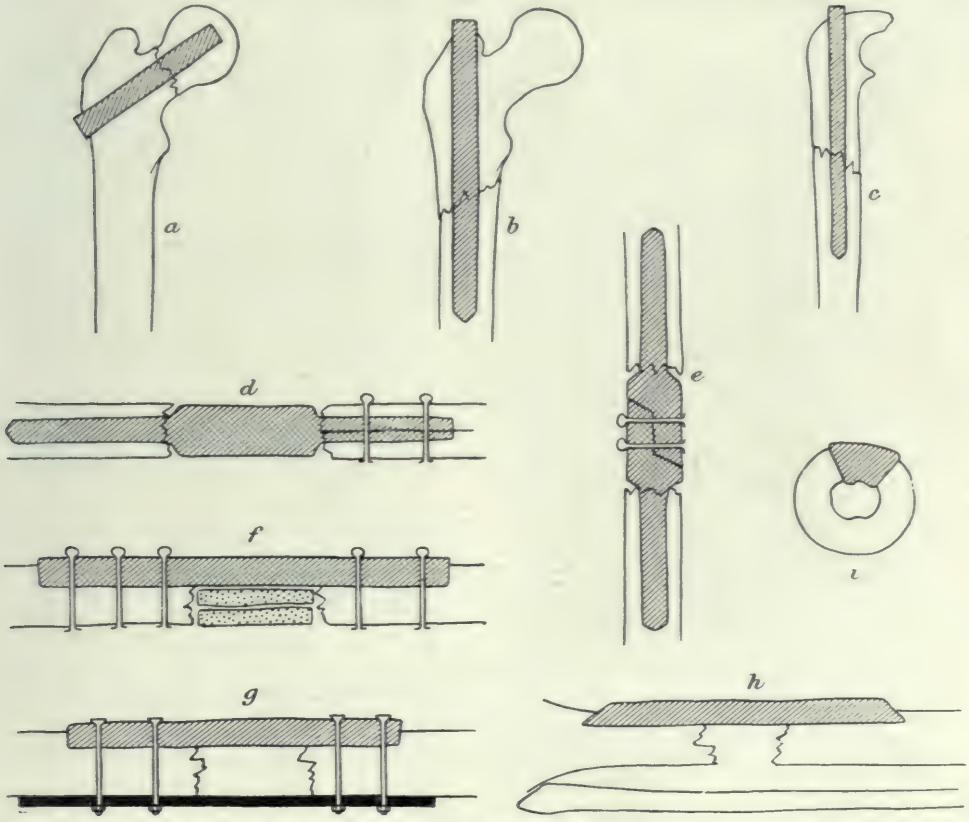


FIG. 207.—Showing methods of fixing and fitting a graft: (*a*) Graft driven into trochanter, neck, and head of femur; (*b*) Graft driven into medulla of upper third of femur from trochanter; (*c*) Graft driven into medulla of proximal part of ulna from olecranon; (*d*) Graft tightly fitted into both fragments of a fracture. At one end the shaft has been split for its reception, and then pinned together; (*e*) Graft tightly fitted into both fragments of a fracture. The graft has been cut by a fret-saw in a Z manner and pinned together afterwards; (*f*) Graft fitted as a cortical strut and fixed by pins. The fragments marked by dots have been cut from the shaft and used to fill up the gap between the main ends of the bone; (*g*) Graft fitted as a cortical strut and bolted to a plate on the opposite side of the bone; (*h*) Inlay graft fitted and fixed without metallic sutures; (*i*) Section of the inlay graft, showing its wedge shape.

Case 58.—Still has the steel strut in the femur, but there is a septic discharge from the original wound (*Figs.* 194, 195).

Case 59.—Never did well. The patient had a big scar right down to the bone, and this broke down badly in spite of plastic suturing. The peg was removed after four weeks, and later the leg was amputated at his own wish. Both these cases (58 and 59) were instances of non-union and sepsis more than twelve months after injury, and it is open to question whether any method would have been more successful.

Case 60.—Altogether exceptional, I think, but the result was so tragic that I do not feel justified in trying to explain it away or in suppressing it. It was a simple fracture with non-

union of three months' standing. I used a peg made of ivory, 6 in. long by ½ in. thick (*Figs.* 199, 200), and the result was apparently quite perfect. But eight weeks later, when the wound had healed, the patient developed influenza, which was then very prevalent in the hospital. His thigh swelled up and became very painful. The incision, being reopened, revealed much blood-clot and some pus, and he died two days later of septicæmia. The specimen recovered post mortem shows apparently perfect union of the bone.

I have seen one other case comparable to this which is worth recording. It concerns the patient of a colleague, who had plated a simple fracture of the tibia. This had healed well, and patient had been discharged to an auxiliary hospital, where he contracted influenza two months later. When he had got over this, the leg was swollen and painful, and he was re-admitted to our hospital. There it was found that he had an abscess at the site of the plating operation, and also pyæmic infection of both knee- and ankle-joints of the same limb. The plate was removed and the joints were drained, and he is making a good recovery.



FIG. 208.—Radius from *Case* 2, with characteristic displacement.



FIG. 209.—Same case after operation by tibial graft. It failed, and illustrates well the causes of failure. There is insufficient contact between the graft and its bone bed, and what contact there is concerns unhealthy atrophied bone.

However, having quite honestly stated the facts, I may go on to express my own opinion that this method of introducing a long internal peg into the femur from the trochanter is one of some value in special cases, and the unfortunate occurrence of an exceptional sequel would not deter me from employing it on another occasion.

4. **Special Methods of Operation of Occasional Value.**—In certain cases no classical method of bone repair can be adopted, and special devices may be employed. Such are illustrated by four cases of the present series.

Case 31.—Loss of bone just below the head of the humerus (*Figs.* 201, 202). After very long preliminary treatment and the removal of sequestra, the wound healed. Then the following operation was performed. The seat of fracture was exposed, and the lower fragment, shaped in

a conical fashion, was made to fit into a cavity in the head of the humerus. There was no room for any kind of plating, and a simple wire suture would certainly have cut out. Each fragment was drilled from side to side by a $\frac{5}{16}$-in. drill, and into each hole was passed an ivory tube carrying a $\frac{1}{16}$-in. iron wire. The ends of the wire were twisted together in the manner shown, after the fragments had been pressed into position. Unfortunately the ends of the wire were cut too short at one side, and here eventually the junction gave way; but nevertheless firm and good union took place, and the man has now quite a useful arm.

Case 25.—Loss of substance in the radius, associated with a gap in the flexor muscles over that bone. In this case I removed a piece of the ulna of sufficient length to allow of suture of the muscles, and the ends of the radius came together. The ulna was joined by a step-cut operation; but although the muscles have united well, and are functioning, the bone has not united; and if this continues for six months, I shall perform a bone-grafting union.

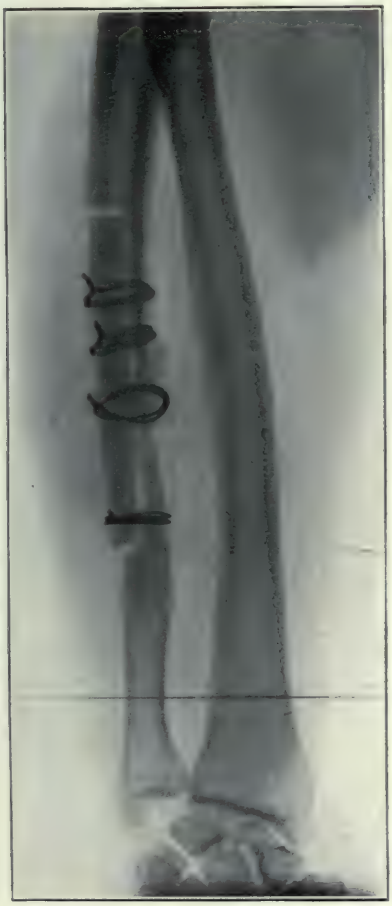


FIG. 210.—Ulna from *Case* 15, treated by a naked tibial graft fixed by encircling wire. The gap between the bone ends has been filled by the bits cut out for reception of the graft. Complete success.



FIG. 211.—Humerus from *Case* 28 after the removal of the bone graft. Illustrates the stimulation of new bone formation by the graft. Firm union ultimately resulted.

This type of operation, consisting in the removal of a segment of one bone in order to allow the falling together of its fellow, has, I think, a definite scope which is more important than is represented by the single case mentioned. It is applicable to certain fractures of the forearm and of the tibia. In the forearm, I should reserve it for those cases with a gap in the muscles as well as in the bone; because if the former are intact, I think that bone grafting, after making good the scar, is the best treatment. In the case of a tibia with a small gap between the fragments, it is a good operation, because division of the fibula will allow the tibia to come together with very little shortening (i.e., provided the gap is small), and this is a short and easy procedure compared with bone grafting.

Cases 30 and 40.—These are instances of the loss of the lower part of the humerus in arms which were much scarred and had been very septic. I divided the ulna at the junction of its middle and lower third, separated the proximal portion from its muscles, and turned it upwards, driving its lower end into the proximal fragment of the humerus. In one case this failed, and in the other it succeeded after partial exfoliation of the reversed ulna, so that I do not feel that the method has much to recommend it.

5. **Bone Grafting.**—To this method we shall devote a separate section.

V. BONE GRAFTING.

The introduction of a living autogenous bone graft is the main resource for the treatment of ununited fractures, and especially for those in which there has been definite loss of substance. Unfortunately, however, in the case of gunshot injuries there exist certain



FIG. 212.—Radius from *Case* 8, before operation. There was displacement and non-union.



FIG. 213.—The same case after operation by tibial graft. The graft is fixed to each fragment by split-pins.

drawbacks and difficulties which make it much more difficult of success than when it is applied for the replacement of bone lost by disease—e.g., a tumour or tuberculosis. These, which have already been alluded to, are the existence of latent sepsis and the presence of extensive scars of skin, muscle, and bone.

I have recently (BRITISH JOURNAL OF SURGERY, Oct., 1917) summarized the historical account of bone grafting, and dealt fully with experimental evidence in relation to the subject, and I therefore confine myself in the present paper to clinical conditions, with special emphasis on this point, that the cardinal factors of latent sepsis, scar tissue, and deformities are features of the clinical problem not represented in experimental work.

Vital Conditions.—These must be considered in relation to the bed and the graft. The essential condition to be obtained in the bed is the removal of scar tissue, whether cutaneous, fibrous, or osseous. Ragged bone ends must be removed, and no dependence placed upon them for osteogenesis or union.

The necessary vital conditions of the graft are more readily obtained, because this will always be taken from a healthy bone.

That a living autogenous graft continues to live in its new position when joined to living bone is no longer a matter of theory or microscopic investigation. It is proved by many facts, the most convincing of which is, that when a graft becomes fractured, it produces callus just as does a living bone. This has been shown by many human cases and also by animal experiments



FIG. 214.—Fractured forearm bones from *Case* 6. There is mal-union of the ulna and non-union of the radius.



FIG. 215.—The same bones after operation. The ulna has been rectified by a step-cut operation, and the radius united by a long tibial graft, both fixations being effected by split-pins. Complete success.

That *the periosteum* is not an essential element in the graft is proved by the fact that in many cases a naked graft heals in position and becomes united to its bed (*Cases* 11, 15, *Fig.* 210). The best example of this is in the living tibial peg driven into the neck of a fractured femur. Nevertheless, the preservation of the periosteum is very desirable in all cases except those where the graft is entirely intramedullary. There are two reasons for this. The most important is that the periosteum is the medium through which new blood-vessels most readily make connection between the graft and its surroundings. It is the natural vascular envelope of the bone, which is ready to take up a new blood-supply. Secondly, removal of the periosteum involves the removal of the very important superficial layers of osteoblasts, from which more bone growth takes place than anywhere else in the graft. Further, the preservation of the periosteum affords a ready method of suturing the graft in its place in those methods where no metallic sutures are employed.

The rôle of the periosteum is remarkably demonstrated by the comparison of three types of operation :—

1. Where a naked graft is used, increase in thickness of the graft, even after long survival, is very slow. Whenever sepsis supervenes, the graft becomes entirely exfoliated without depositing any new bone (*Cases* 1, 2, 3, 10, 11, 16, 28, 29).

2. Where periosteal flaps with a thin layer of bone are turned down to bridge the gap, no new bone is deposited, and failure results. This shows that periosteum, even when retaining its attachment, will not deposit new bone in an adult (*Case* 20).

3. Where a graft covered on one surface by its own periosteum is used, its behaviour is different from either of the above groups. Increase in thickness occurs



FIG. 216.—Fracture of the radius from *Case* 12.



FIG. 217.—The same bone after union by a graft. The upper end of the graft has been driven into the marrow cavity of the proximal fragment, and the lower end placed in the cavity of the distal fragment after splitting the bone. United by two pins. Complete success.

in all cases within a few months. In those cases where secondary sepsis supervenes, there is an abundant deposit of new bone between the periosteum and the graft. The solid portion of the graft may be exfoliated, but a mass of new bone is left behind of larger bulk than that originally used. In *Case* 5, *Fig.* 220, for example, a periosteum-covered graft was bolted to the radius, to an aluminium plate on the opposite surface. Four months later a sinus persisted. There was massive new bone formation, and on removal of the plate and bolts ready healing took place, the gap being more than filled by new bone. In *Case* 9, two grafts were bolted to opposite surfaces of the incomplete radius, each having a periosteal covering on its outer side. A sinus developed, and persisted. Five months later the wound was opened up. One graft had undergone a central necrosis, the rest being incorporated with the living

tissues. The other graft had almost entirely necrosed in its solid portion, but there was a mass of new bone forming an involucrum on its surface. There was firm and solid new bone filling the gap, although a large amount of the dense bone put in was lost.

Thus we have three facts: (1) Naked grafts form new bone very slowly and scantily; (2) Periosteal flaps in adults form no new bone at all; (3) Bulky grafts covered by periosteum are capable of depositing thick new bone in the form of an involucrum. From these facts it may be inferred that the osteoblasts necessary for new bone formation are contained in the dense bone, but that the protecting and vascularizing matrix of the periosteum is necessary for their activity.

The best source of the graft has been much discussed, but for repair of the long bones I think that the crest or internal surface of the tibia holds most advantages. From this bone the greatest length and strength can be obtained with the minimum exposure or damage to soft parts. It is well provided with thick periosteum, and is readily accessible for accurate sawing. From the crest may be obtained a strong bone $\frac{3}{4}$ in. square in section, and from the surface a long thick plate $1\frac{1}{2}$ in. wide and $\frac{3}{8}$ in. thick. The only serious objection which can be urged against the use of the tibia is the fact that fracture sometimes occurs in it after the removal of a thick graft. This has happened in two of my cases, but in each it was only a small fissured fracture without displacement, and I do not regard it as of serious import ance. The fibula has some points to recommend it. These are, that it presents a rod-shaped bone which requires no cutting, and that it is not an essential feature in the skeleton; but it is very variable in its shape and size, and it is difficult to clear it of muscle without stripping it of its periosteum. With a proper motor saw a good graft can be cut from the tibia much more quickly than from the fibula, in the case of a muscular leg.

In determining the size of the graft two points must be borne in mind. First, that no new bone of any mechanical importance can be expected to arise from it for many months, and that it must therefore be cut large enough to fill the gap it has to replace as far as possible. Secondly, that as the graft ought to have contact with a wide surface of bone bed on each side, it must be cut of sufficient length to secure this. The ideal length is not less than three times that of the gap. For example, if there is a gap of two inches between the main fragments after their unhealthy ends have been cut off, then the graft ought to be six inches long.

A further vital condition to be considered is that relating to the contact between the graft and its bed. Rapid and sound union will depend upon broad and accurate contact efficiently maintained, and it must be a main object of the technique to secure such contact. Just as bone gaps are filled very slowly or not at all, so any spaces between the bone graft and its bed offer obstacles to bony union. Next to the importance of eliminating latent sepsis and scar tissue, nothing has impressed me more than the dependence of success in bone grafting upon this accurate contact. A reference to *Figs.* 208, 209, from one of my earlier cases, will at once illustrate the type of union which is doomed to failure.

Mechanical Fixation.—The success of all plastic surgery depends largely upon accurate suturing. Bone, being a tissue of slow growth and slow repair, requires more firm and lasting sutures than the soft tissues. There are three methods used for the fixation of a graft; (1) *Suture by ordinary absorbable ligatures;* (2) *Fitting by accurate joinery;* (3) *Fixation by means of metal screws, pins, wires, or plates.*

1. The first method, that of ordinary suture—i.e., of the periosteum of the graft to that of its bed—is only suitable for situations where there is no tendency to movement or displacement, e.g., in the repair of defects in the cranium; here, indeed, no sutures are really necessary. In the long bones, catgut or animal-tendon suture cannot be regarded as a serious method of fixation except for the attachment of the periosteum. If any strain has to be borne by ligatures in the fixation of a graft, then my own choice would be of some metal suture, e.g., a bolt or a pin; but

failing such, I think it is better to use a piece of the patient's own fascia or tendon than to place any reliance upon catgut or animal tendons. In the leg, strands of the fascia lata, and in the arm a piece of the palmaris longus tendon, are far better suture materials than pieces of sheep's intestine or kangaroo tail.

2. The method of fixation always to be aimed at is that of fitting the graft into a slot or cavity in the bed in such a way as to require no suture at all. When this can be well done, the method in my experience never fails, provided latent sepsis has been eliminated and scar tissue removed. The simplest type of this fixation is seen in the use of a square tibial peg driven into the cancellous tissue of the femoral neck



FIG. 218.—Forearm from *Case* 22. The ulna had been lost in childhood from osteomyelitis. Patient had nevertheless served as a soldier until he dislocated the head of the radius.

for fracture of that bone. I have never had a failure with this operation, and *Cases* 46, 48, and 52 are good examples. *Case* 46 has been under observation for more than a year (*Figs.* 203, 204). Although he was discharged from the army by a medical board, who evidently were sceptical about reconstructive bone surgery, he has now such perfect function in walking and running that it is impossible to detect which is the injured leg.

In the same way, the living intramedullary peg can be used as a graft for the repair of fractures in certain situations, viz., the upper or proximal third of the femur or ulna. That is to say, in both these situations a peg can be firmly driven into the

shaft of the bone so that graft and bed are firmly contacted in the whole length of the former. It must be carefully noted that this is a very different procedure from putting a living intramedullary peg into the site of a fracture, introducing it into one broken end and then bringing the other over it (as in the use of the short pegs described above). This latter procedure is by clinical and experimental evidence likely to fail, because the peg is so short and the fitting so loose. In the firmly-fitted living peg the shaft of the bone should be drilled much smaller than the peg, and the peg should not be round but angular in section. For example, in the femur the shaft is hollowed by a $\frac{3}{8}$-in. drill, which leaves a margin of at least $\frac{1}{8}$ in. of fairly



FIG. 219.—The same arm after insertion of a long tibial graft fixed above by two split-pins.

soft bone all round the cavity. A square peg is cut from the tibia, 6 in. long and $\frac{5}{8}$ in. thick, and then filed down so as to pass through a $\frac{1}{2}$-in. hole. It then has a roughly octagonal section, and can be hammered into the $\frac{3}{8}$-in. hole so as to hold very firmly, and 3 in. will lie on each side of the line of fracture.

There are two other methods by which a graft can be firmly fitted as an intramedullary peg, and these are specially suited for cases where there has been a loss of substance (*Fig.* 207). Suppose that the gap to be filled is 2 in. after removal of unhealthy bone from the ends of the fragments; suppose that it is the radius to be repaired, having an outside diameter of half an inch and an inside cavity of a quarter

of an inch. The graft is cut square and of 6 in. length. Each end is shaped with a file for 2 inches, until it fits tightly the holes drilled in the fragments. Into one fragment the graft is driven (temporarily wrapping the bone round with several turns of wire to prevent splitting). The other fragment is cut for 2½ in. with a fret-saw, and the two halves are prized apart so as to take the spindle at the other end of the graft. Then this split end and the contained graft are sutured through two holes by suture or split-pins (*Fig.* 216, 217). In the alternative method, which is to be used if one fragment of the bed cannot be split as above described, the graft, having been shaped so as to fit at each end, is itself cut into two portions by a Z-shaped incision. Each half is hammered into place, and then the graft fitted together and sutured or pinned.



FIG. 220.—Radius from *Case* 5.

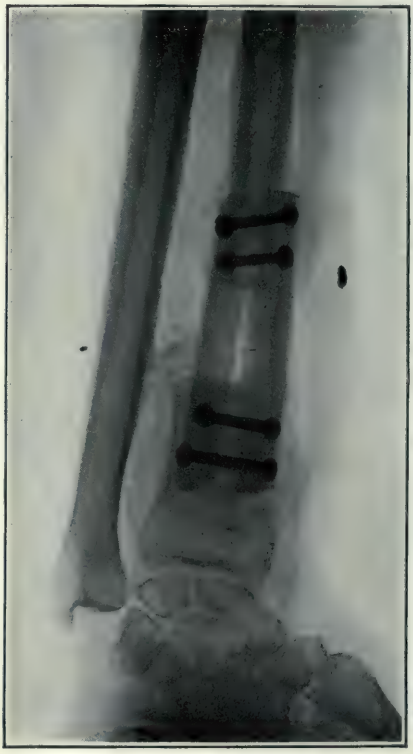


FIG. 221.—The same after operation. The bone has been united between a tibial graft and an aluminium plate by four bolts.

The inlay cortical graft, which has been used and popularized by Albee, is a superficial graft, laid down in a slot cut for it in the cortex of the bone to be mended. Albee uses a twin saw, but if the same twin saw be used to cut the graft and the slot into which it is to fit, then the latter will be too large by two saw thicknesses, and for strong work I think it is better to make a shelving trough, cutting each side separately with a simple saw-cut. Then the graft can be hammered down into its bed, the hollow bone having enough elasticity to open a little for its reception. The ends of the graft should be bevelled so as to underlie the ends of the slot. Thus the muscular tension will prevent the graft from slipping out (*Fig.* 224).

In some cases one end of the graft may be shaped as a peg and driven into

the marrow cavity, while the other end is recessed into a flat cut on the other fragment and there secured by pins (*Figs.* 222, 223).

3. Finally, the use of wire nails, screws, bolts, or plates as a method of fixation must be considered. And in this connection it is wise to hold a temperate and reasoned opinion which avoids impracticable extremes. The fact that wire, plates, and screws have often been unwisely used and caused trouble, is not sufficient reason to reject metallic suture when this will afford definite advantages. That there is nothing essentially hostile to a graft in the presence of metal sutures is proved by the many cases in which success has followed this method of fixation. In 13 out of 19 successful cases in the present series metal sutures were used. If it is admitted on the one hand that firm fitting without metal sutures is always the ideal method of grafting, it must, I think, also be granted that firm fixation by metal sutures is better than insecure fixation without, and I have given experimental demonstration of this. There are many cases where the graft has to be laid with some tension—i.e., the graft itself has to act as a splint securing alinement. Such a case is well illustrated by the common fracture of the radius—cf. *Case* 6, *Figs.* 214, 215. In such a case, if a strong graft is securely bolted or pinned to its bed, then it will heal well; whereas if it was merely tied in its place, it would surely allow angulation to occur, and probably the graft would be extruded.



FIG. 222.—Forearm bones from *Case* 23. There was mal-union of the radius and a large gap in the ulna.



FIG. 223.—The same bones after operation. As the radius was displaced away from the ulna, it was left alone. The ulna was united by a long tibial graft, pegged into the lower fragment and united to the upper by two split-pins.

I have successfully used encircling iron wire, split-pins, bolts, and plates for the fixation of a graft, and these various methods are so well shown in the accompanying radiograms that it is hardly necessary to describe them in detail. The split-pin is, however, the method which gives me the greatest satisfaction. These pins are the ordinary cotter-pins to be bought at any ironmongers. I use them in thicknesses of $\frac{1}{16}$, $\frac{3}{32}$, and $\frac{1}{8}$ in. The bone bed and the graft are perforated by a suitable drill, the pin thrust through, and its ends are turned up and cut off and pressed home (*Figs.* 213, 219).

Another point to be borne in mind is that the use of firm metal fixation will greatly simplify after-treatment, inasmuch as much less plaster-of-Paris immobilization



FIG. 224.—Tibia from *Case* 43. Successfully united by an inlay graft from the opposite tibia fitted without the use of metal sutures.

is then required. In the forearm bones, for example, the limb is kept on a simple splint for a few days until the smooth healing of the wound is secured; then plaster is applied for two or three weeks; and after this the man is set to light work without any splint or plaster of any kind; and I claim that in this way much more rapid restoration of function is obtained than by keeping the limb for months in plaster.

Results obtained by Bone Grafting in the Present Series.—The series contains 34 cases of autogenous bone grafting. Of these, 10 (29·4 per cent) have been failures, 5 (14·7 per cent) have been eventual successes in producing bone union after extrusion of the graft (*Fig.* 211), and 19 (55·8 per cent) have been complete successes.

The results are further analyzed in the following table:—

	NUMBER OF CASES	FAILURES	PARTIAL SUCCESSES	COMPLETE SUCCESSES
Radius	10	3	1	6
Ulna	12	4	1	7
Humerus	3	1	1	1
Tibia	4	1	2	1
Femur	5	1	—	4
Totals ..	34	10	5	19

The most important matter for consideration is that of the failures and their causes. In every one of the 15 cases where success was not complete, the cause of failure can now be traced.

In four cases (1, 2, 10, 14) the operation was performed much too early, i.e., in periods of a few days up to three weeks after healing.

In three cases (3, 17, 42) only scanty contact between the graft and its bed was secured.

In one case (13) a sliding graft was done; that is to say, sclerosed avascular bone was taken from one fragment and made to bridge the gap.

In one case (18) the patient fell on his arm and broke the graft, bursting open the wound.

In one case (29) the graft was laid in unhealthy bone which should have been removed.

In one case (56) too complicated a procedure was adopted, and the patient died of shock.

In one case (28) the humerus was not immobilized adequately, and the arm, hanging on the graft, broke the fixation.

In two cases (41 and 44) scars in front of the tibia were not sufficiently replaced by healthy tissue before grafting.

In one case (20) periosteal flaps with thin bone scales adhering to them were turned down over the gap, and produced only a shred of bone.

In contemplating these results, my feelings are those of mingled disappointment and hope—disappointment that the proportion of successes has been so small, and hope that by the experience gained one may be able in the future to avoid causes of failure which are seen to be so obvious, and therefore so possible of evasion.

In conclusion, it is my pleasant duty to thank Dr. Honeyford, Captain Moore, and Captain Wace for the indispensable help they have given me both in the operations and after-treatment of these cases.

[*Particulars of Cases on next page.*

PARTICULA

Case and Age	Bone	Cause of Non-union	Period	Operation
1 Pte. W. W. Age 39	Radius	Gap 1½ in.	5 months non-union, 3 weeks healed	Naked tibial graft, fixed by wire..
2 Cpl. C. N. Age 21	Radius	Gap 2 in.	10 months non-union, just healed	Naked tibial graft, fixed by wire (*Figs.* 208, 209) ..
3 Pte. J. C. Age 24	Radius	Gap 1½ in.	10 months non-union. 2 months healed	Naked tibial graft, fixed by one wire and one ivory nail each end
4 Pte. C. S.	Radius	Gap ½ in. and displacement	12 months non-union, 5 months healed	Fibula graft, fixed by one wire and two ivory nails at each
5 Pte. T. Q. Age 36	Radius	Gap 1 in. and displacement	6 months non-union, 4 months healed	Excision of scar. Tibial graft with periosteum supported a metal plate (*Figs.* 220, 221). No after-splint used
6 Gnr. S. W. Age 41	Radius	Gap 2 in.	5 months non-union, 3 months healed	Preliminary scar excision 1 month before bone operat Mal-union of ulna corrected and united by step-cut. Tibial graft with periosteum fixed at each end by two sp pins (*Figs.* 214, 215).
7 Gnr. T. S. Age 37	Radius (closed fracture)	Displacement	1 month non-union, no wound	Curved ivory plate, fixed by 6 ivory nails.. ..
8 Sgt. C. W. S. Age 40	Radius	Displacement	8 months non-union, 7 months healed	Attempt to use a sliding graft abandoned because of tens necessary to secure alinement. Tibial graft with periost fixed by 5 pins (*Figs.* 212, 213).
9 Pte. W. A. R. Age 20	Radius	Gap 2 in.	13 months non-union, 3 months healed	Preliminary replacement of scar tissue by skin flap from ch Two tibial grafts with periosteum bolted together, one s side of fragments
10 Pte. J. G. Age 35	Radius	Gap 2 in.	10 months non-union, recently healed	Naked tibial graft, fixed by wire. Scar tissue was not rem
11 Pte. J. McM. Age 28	Radius	Gap 1½ in.	4 months non-union, 3 months healed	Naked tibial graft fixed by wires
12 L-Cpl. R. G. Age 35	Radius	Gap 1 in.	10 months non-union, 4 months healed	Preliminary operation for removal of scar and bone débr Tibial graft with periosteum, 5 in. long, shaped as a p at each end, driven into marrow cavity of shaft at one e and let into the other after splitting (*Figs.* 216, 217)
13 Pte. H. T. Age 27	Ulna	Displacement	12 months non-union, 3 months healed	Sliding graft. The bone was very dense and avascular. marrow cavity being obliterated
14 Pte. G. W. Age 27	Ulna	Gap 2 in.	4 months non-union, recently healed	Sliding graft, fixed by wire
15 Pte. D. McC.	Ulna	Eburnation and plating	17 months non-union, 12 months healed	Plate and four screws which were loose removed. Multip drilling of ends to promote vascularity. Tibial graft wit out periosteum fixed by wire (*Fig.* 210)
16 Cpl. G. E. Age 23	Ulna (closed fracture)	Displacement	18 months non-union, no wound	Five previous operations, wiring and plating, had been don Sliding bone graft
17 Cpl. A. G. P. Age 25	Ulna	Displacement and gap ½ in.	11 months non-union, 3 months healed	Fibula graft, fixed by two nails and one wire to each fr ment

CASES.

ULT	REMARKS
ure	Operation was done within 3 weeks of healing of wound, and the scars were not excised as a preliminary. Chronic suppuration from 7th day onwards until removal of graft after 5 months. Some new bone had formed, but not enough for union.
ure	Operation done directly wound had healed. Whole of scar tissue sloughed. Graft removed after 3 months. Gap reduced to 1 in. but no union. There was obviously insufficient contact between the graft and its bed (*Fig.* 209).
ure	Operation 2 months after healing. Suppuration not manifest until 10 days after operation. Graft removed after 4 months.
ess	Five months after operation, good function in hand.
ess	There was such a strong tendency to displacement of both radial fragments towards the ulna that a plate was necessary to reinforce the graft. Good strong hand-grip 8 months after operation.
ess	Five months after operation has a strong hand-grip with supple movements, including rotation of wrist. Within two months of operation he could do basket-making, wearing only a light cock-up splint.
ess	Rapid recovery of function. Discharged to military duty after 2 months.
ess	Rapid recovery of function. Discharged to Command Depôt 2 months after operation.
ess	Remarkable instance of the value of the periosteum. Four months after operation a sinus persisted. Wound opened: the dense parts of the graft were partly necrosed, but there was a heavy deposit of new bone from the superficial parts of each graft, forming a perfect union.
ial ess	Premature operation. Scars should have been excised. The scar tissue broke down, and the graft was in part extruded. Much new bone was deposited, so that weak union was established.
ess	An example of success with a naked graft without periosteum. After 2 weeks, massage begun. After 2 months, discharged for military duties.
ess	Very satisfactory result. After two weeks in plaster he wore only a light cock-up splint and was able to do basket-work. Three months after operation his arm is almost normal.
ure	The incision healed, but the original scar broke down. This should have been excised as a preliminary. It would have been better to have taken a tibial graft, because the ulna itself had become so eburnated.
ure	Premature operation. All the scar tissue broke down, exposing the graft.
ess	The drilling of the fragments was done to cause union, but failed in this object until the bone graft was used two months later. Firm union and good functional result.
ess	Two months later, good functional result, and patient was discharged to Command Depôt.
ial ess	Ten days after healing the wound broke down. After 4 months the graft was removed. There was some new bone and a weak union.

Continued on next page

PARTICULARS

CASE AND AGE	BONE	CAUSE OF NON-UNION	PERIOD	OPERATION
18 Pte. J. L. Age 23	Ulna	Gap 1½ in.	9 months non-union, 3 months healed	Long naked tibial graft, fixed by wire and ivory nails
19 Pte. G. A.	Ulna	Gap 1 in.	9 months non-union, 4 months healed	Sliding graft, fixed by wire
20 Pte. A. G. Age 38	Ulna	Gap 1½ in.	10 months non-union, 4 months healed	1. Scars excised as a preliminary. 2. Two flaps of periosteum 3 in. long turned down fro upper fragment and sewn to lower, taking a thin layer bone with them
21 Pte. E. C. Age 19	Ulna	Displace-ment	6 months non-union, 4 months healed	The ulna was overlapping, and was united by a step-c operation. (The radius had been fractured but was unite
22 Pte. R. G. I. Age 42	Ulna	Old osteo-myelitis	34 years non-union, no recent wound	The radius was dislocated, and it was this which caused t disability. Ulna replaced by a long tibial graft with periosteum, united above to the olecranon by pins. He of radius removed (*Figs.* 218, 219).
23 L-Cpl. F. C. Age 23	Ulna	Gap 3 in.	18 months non-union, 5 months healed	Two preliminary operations for removal of scars and sequestr Long tibial graft with periosteum : lower end, peg-shape driven into distal fragment ; upper end fixed by pins
24 Pte. G. J. Age 22	Ulna	Gap 2 in.	12 months non-union, 4 months healed	Operation exactly similar to last
25 Pte. H. C.	Ulna and radius	Gap 1 in.	6 months non-union, wounds un-healed	Ulna was shortened, and united by a step-cut. This allow the radius to come together and the divided muscles to sutured
26 Lt. W. A. C. Age 25	Ulna and radius	Eburnation and plating	8 months non-union, no wound	Step-cut operation for both bones ; joined by bolts (*Fig* 182, 183, 184, 185)
27 Pte. J. S. Age 35	Radius and ulna	Necrosis	—	Operation revealed a number of small bits of bone betwe the main fragments. These were removed, and both bon united by a step-cut
28 Sgt. R. A. Age 34	Humerus	Gap 1 in.	8 months non-union, 3 months healed	Naked tibial graft, fixed by four wires
29 Pte. F. B. Age 33	Humerus	Gap 1¼ in.	11 months non-union, 4 months healed	1. Naked tibial graft, fixed by four bolts. 2. After failure of graft the bone was fixed by two aluminiu plates
30 Pte. T. S.	Humerus	Loss of lower third of bone	7 months non-union, 3 months healed	Ulna cut through and turned up and pegged into humerus
31 Pte. H. M. Age 41	Humerus	Gap 1½ in.	15 months non-union, 3 months healed	Shaft shaped as a peg and impacted into head, fixed by tw wires threaded through ivory tubes (*Figs.* 201, 202)
32 L-Cpl. C. H. Age 26	Humerus	Displace-ment	7 months non-union, 3 months healed	Step-cut operation, united by two bolts
33 Pte. J. R. Age 27	Humerus	Gap 1½ in.	17 months non-union. 3 months healed	Several preliminary operations for removal of scar tissue. Step-cut operation, using a natural spur of the upper end one step

ES—*continued.*

LT	REMARKS
ure	Twelve days after operation patient fell on his arm, fracturing the graft and breaking open the wound. Two months later graft removed.
ess	Rapid recovery of function. Discharged to civil employment after 3 months.
ure	An instructive example of the feeble osteogenesis of periosteum. After 4 months two little lines of bone could be seen, but there was no skeletal union; 6 months after operation a sinus formed, and both pieces of bone were extruded.
ess	Discharged for military service.
ess	So much shortening of the arm had occurred that it was impossible to replace the radial head. His arm is now fairly strong, his grip is good, and he can flex the elbow to an acute angle and fully extend it.
ess	The radius had been fractured, but had firmly united. It was angulated away from the ulna and therefore not re-fractured. No splint was worn, and rapid restoration of function took place.
ess	Discharged for civil employment.
ial ess	A part of the radius and the overlying flexor muscles had been blown away. Only by shortening of the ulna could the muscles be restored. The muscles are now acting well, but the radius has not yet united.
ess	A simple fracture, perfectly plated, but in spite of primary healing non-union occurred, the screws being loose. Good strong arm 3 months after the step-cut operation. Returned to military service.
ial ess	Suppuration occurred and was difficult to cure. After 6 months there was good union in both bones, but it it is clear that the bits of dead bone should have been removed before anything else was done.
ial ess	If the arm had been put up in plaster it would probably have succeeded. As it was, the weight of the arm pulled the graft out of place, and the latter had to be removed after 4 months. Good union occurred from callus stimulated by the graft (*Fig.* 211).
ure	Failure in both cases was due to not going wide enough of the unhealthy wound and taking hold of good bone tissue. He is waiting for a further operation.
ure	He had complete musculospiral paralysis, and after failure of this operation the arm was amputated.
ess	There was no room for any form of plate or graft. The only alternative would have been removal of the head of the humerus. By passing the wires through ivory tubes, the former were prevented from cutting out.
ess	There had been musculospiral weakness, which rapidly recovered after the bone operation. It must have been due to dragging on the nerve. Discharged after 3 months to military service.
ure	It was a mistake to rely upon an end of unhealthy bone for union. It should at any rate have been reinforced by a plate. The upper step broke off, and, after discharge of patient to another hospital the arm was amputated.

Continued on next page

PARTICULARS

CASE AND AGE	BONE	CAUSE OF NON-UNION	PERIOD	OPERATION
34 Pte. H. G. Age 32	Humerus	Displacement	6 weeks non-union, no wound	Short ivory intramedullary peg (*Fig.* 192) ..
35 Sgt. J. H. Age 32	Humerus	Displacement	7 months non-union, 2 months healed	Step-cut operation
36 Sgt. G. P. Age 25	Humerus	Gap 1 in.	6 months non-union, 3 months healed	Step-cut operation, reinforced by double aluminium
37 Pte. J. R. Age 23	Humerus	Gap 1 in.	13 months non-union, 1 month healed	Step-cut operation, supported by two plates bolted to
38 Pte. A. B. Age 24	Humerus	Loss of lower third	7 months non-union, 3 months healed	Tibial graft driven into lower end of humerus as a pe
39 Sgt. F. R. Age 23	Humerus	Necrosis	12 months non-union, 3 months healed	Step-cut operation, bolted. Necrosed fragments were in some pus
40 Pte. J. B. Age 32	Humerus	Loss of lower third	10 months non-union, 6 months healed	Ulna divided at lower third, turned up, and pegge humerus
41 Pte. J. C. Age 25	Tibia	Gap 1½ in.	12 months non-union, 3 months healed	Graft from opposite tibia, fixed by wires
42 Pte. J. L. Age 22	Tibia	Gap 1 in.	2 years non-union, 6 months healed	Graft from opposite fibula bolted through the tibia to of same side
43 Pte. W. S. Age 30	Tibia	Gap 1½ in.	13 months non-union, 2 months after excision of scar	Preliminary scar excision. Inlay graft from opposite fitted without suture. Plaster-of-Paris for three m (*Fig.* 224)
44 Sgt. F. H. Age 30	Tibia	Gap 2 in.	8 months non-union, 3 months healed	Inlay graft from opposite tibia fixed by wires. The graft was prepared six weeks before use by multiple d *in situ*
45 Pte. W. F. Age 20	Femur, middle	Displacement	3 months non-union, no wound	Bolted plate
46 Pte. A. C. Age 22	Femur, neck	Displacement	3 months non-union, 2½ months healed	Tibial bone peg (*Figs.* 203, 204)
47 Cpl. R. J. Age 24	Femur, middle	Displacement	7 months non-union, 3 months healed	Bolted plate (*Fig.* 177)
48 Pte. J. U. Age 26	Femur, neck	Displacement	12 months non-union, 10 months healed	Previous operation by a single screw, which had bent become displaced. Tibial bone peg
49 Pte. J. H. Age 25	Femur, upper third	Displacement	3 months non-union	Short ivory peg (*Fig.* 193)
50 J. J. Age 49	Femur, middle	Displacement	10 years non-union, no wound	Double bolted plates

ES—*continued.*

ULT	REMARKS
cess	Discharged to Command Depôt.
cess	Slow but good return of function.
cess	The bone had been so widely comminuted that the plates were necessary for strength. Discharged to civil employment.
cess	Operation rather premature. Plates had to be removed after 3 months because of sinus. Good bone union.
cess	The arm was put up flexed, and the end of the graft came through the skin and a small portion had to be removed. It would have been better to put the arm up in extension, so as to bury the graft in soft tissues.
lure	Suppuration. The necrosed bone should have been removed without any further operation.
tial cess	A part of the reversed ulna was exfoliated, but the remainder healed well in its new position, and he promises to have a useful arm.
tial cess	The anterior scars broke down, and the graft was slowly exfoliated piecemeal. There was solid union of the original bone, and sound healing after 8 months.
lure	Too elaborate an operation. There was never accurate fitting between the graft and its bed. Necrosis occurred, and eventually the leg was amputated.
cess	There was a temporary breakdown of the scar and a trifling exfoliation of the graft. Strong firm union. Discharged to civil employment.
ate cess	The anterior scars gave way partially in spite of having been replaced by new skin. The graft was slowly exfoliated, but when it had been entirely removed there was firm union between the original fragments and cross-union with the fibula. Discharged to civil employment, walking well.
cess	Plate removed after 4 months. Perfect union of bone, but much wasting of muscles and a rather stiff knee. Civil employment.
cess	Twelve months later he could walk and run, so that it was impossible to guess which had been the injured leg.
cess	The plate was removed 6 months later because of an abscess. The bone was firmly united and the two legs the same length.
cess	Five months later could walk well. Discharged for civil employment.
cess	It was a clean simple fracture of transverse direction. Hence the suitability for this simple operation.
ath	He was a big man with a fatty heart. The operation was long and difficult. He died 48 hours later, never rallying from the shock of the operation.

Continued on next page

PARTICULAR

CASE AND AGE	BONE	CAUSE OF NON-UNION	PERIOD	OPERATION
51 Pte. J. J.	Femur, middle	Displacement	12 months non-union, 3 months healed	Bolted plate
52 Pte. E. R.	Femur, neck	Displacement	9 months non-union, 8 months healed	Tibial bone peg
53 J. R. Age 50	Femur, middle	Displacement	3 months non-union, no wound	Short intramedullary ivory peg
54 Pte. C. H. Age 22	Femur, lower third	Displacement	3 months non-union, wounds unhealed	Lower end was pressing back on popliteal vessels. Bolted plate, very difficult operation
55 Pte. H. E. Age 24	Femur, middle	Displacement	7 months non-union, 6 months healed	Long graft from the fibula (*Figs.* 205, 206) ..
56 Pte. A. S. Age 25	Femur, upper end	Gap 2 in.	5 months non-union, 3 months healed	Preliminary excision of scar followed by transfixion ext Double graft from tibias. One driven into each fr and then bolted together
57 Lt. L. S. Age 27	Femur, upper end	Displacement	5 months non-union, 3 months healed	Steel cylinder, 9 in. long, pushed down from trochant marrow cavity. Removed after 8 weeks (*Figs.* 196, 1
58 J. R. Age 29	Femur, upper end	Displacement	16 months non-union, unhealed	Steel rod, cross-shaped in section, thrust down the cavity from trochanter (*Figs.* 194, 195)
59 Pte. J. C. Age 24	Femur, upper end	Displacement	10 months non-union, 2 months healed	Had been very septic and a large part of the musc fracture had been lost. Steel rod thrust into marrow cavity
60 Pte. W. B. Age 41	Femur, upper end	Displacement	3 months non-union, no wound	Ivory peg, 6 in. long, ½ in. thick, pushed down from tro into marrow cavity (*Figs.* 199, 200)

S—*continued.*

LT	REMARKS
ss	The friable bone was fractured by the bolts. The plate was removed after 4 months. Eventual sound union. Poor function.
ss	Slow restoration of function.
ss	Slow union, but good result after 6 months.
re	Moist gangrene of the leg due to injury of the popliteal vessels; amputation. Severe tetanus, cured by anti-tetanic serum.
ss	Much comminution, but no scar of wound. Upper end tilted forward. Smooth healing, but very little new bone formation. Still under observation, walking on crutches 6 months after operation.
h	Severe shock, from which he died. It was a mistake to operate on 3 large bones at the same time. Lungs, brain, and kidneys showed fat emboli, but though these were abundant, I do not think that they had anything to do with death.
ss	The bone, especially the upper fragment, was too atrophied to take screws. Six months after operation he is walking well with crutches. There is still an unhealed sinus.
r tion	The rod is still in position, 6 months after insertion. Union is very slowly occurring.
re	The wound gave way over site of fracture, and profuse suppuration, not cured by removal of the rod, was set up. Subsequent amputation.
th	Appeared to do perfectly. Eight weeks after operation developed influenza. Leg swelled, and on being opened was full of blood with a little pus. Death 2 days later. Femur had made a perfect union.

THE TREATMENT OF DISABILITIES OF THE UPPER EXTREMITY IN MILITARY SURGERY.

By Major NAUGHTON DUNN, R.A.M.C., Birmingham.

Of the cases admitted to a military orthopædic hospital, 48 per cent suffer from some disability of the upper extremity. In many, the wounds are healed ; but in practically all there is limitation or loss of movement in one or more of the joints of the limb. Owing to the recognition of the fact that the best artificial arm is a poor substitute for the original, every effort is made to avoid amputation in the acute stage ; it therefore falls to the lot of the orthopædic surgeon to solve many problems of extreme interest and difficulty. The risks incurred in saving limbs abroad are only justified if we in this country can restore them to at least a moderate degree of usefulness. One knows that much disability is inevitable, owing to pressure of work both abroad and at home, but it is important that all surgeons should realize the important principles of treatment, and how and when to apply them.

The hand being the essential part of the upper extremity, I propose to deal first with its disabilities and their treatment. With one exception—suture of nerves—restoration of grasp should be our first endeavour. Once useful movement of the thumb and fingers is procured, the patient's enthusiasm is enlisted, and the surgeon is assured of his active co-operation in any further operative procedure necessary to mobilize or alter the position of the larger joints. An exception to this rule is made in the case of lesions of nerves, mainly because the period necessary for regeneration—a physiological process without which complete functional recovery is not possible—allows ample time for the treatment of the deformity or loss of movement of the joints themselves.

THE HAND.

Direct Injury.—In cases where there has been direct injury of the hand, with ankylosis of one or more joints and general rigidity of all, our first endeavour should be to get as much functional recovery as possible before resorting to any operative procedure ; until the patient has recovered volitional control of what we know to be potentially possible, plastic surgery is contra-indicated. Frequently the patient has had his arm splinted and slung for many months, and treatment by baths, massage, etc., will be necessary. After a few weeks of this, we find one of three conditions in the fingers : Either (1) There has been very marked improvement ; or (2) The periarticular structures have become thickened, œdematous, and tender ; or (3) There is limitation of flexion, due to the shortening of the structures on the extensor aspects of the forearm or hand.

1. In the first case we force the joint a little further than has previously been done, and the definite snap of adhesions is felt. This is an indication that forcible manipulation under an anæsthetic will hasten recovery.

2. In the second class of case, where there has been considerable reaction to movements without anæsthesia, and the joint tends to spring back to its extended position on further forcing, the treatment should be rest, massage, and gradual flexion later.

3. In the third case, the flexion of all joints is free, but it is not possible to combine their movements. With the metacarpo-phalangeal joints in the extended position, flexion of the interphalangeal joints is possible, but when the metacarpo-phalangeal joints are flexed, the interphalangeal joints resist flexion. In this case, again, we must depend on graduated splintage. A short cock-up splint is applied to the wrist and fixed with plaster-

of-Paris, which also maintains the metacarpo-phalangeal joints in flexion. The interphalangeal joints will then be extended, and gradual flexion of these will give the stretching of extensor tendons necessary for a good grasp. If the shortened tendons are involved in scar adherent to the metacarpal bones, the scar should be dissected out and free motion of the metacarpo-phalangeal joints obtained before any suture of the tendons is attempted. Flexion of the metacarpo-phalangeal joints should be maintained until the patient can voluntarily increase the degree of flexion obtained by fixation. Where the thumb is adducted, its position must first be corrected, in order to clear the grasp.

In cases with fair movement, but where further recovery is unduly retarded by the ankylosis of one or more joints, pseudarthrosis may be necessary as a preliminary. Remembering that complete movement of individual fingers is not possible in the normal hand where either the third, fourth, or fifth finger is held fixed in the extended position, pseudarthrosis of one or more of these joints may be necessary to allow the full functional recovery of the others.

Common Disabilities of the Hand directly associated with Injuries of Individual Nerves.

1. *Ulnar Nerve.*—Contracture of the interphalangeal joints of the fourth and fifth fingers, hyper-extension of all the metacarpo-phalangeal joints, with rigidity of the fourth and fifth. This condition is due to contracture of the ulnar half of the flexor profundus digitorum, paralysis of the lumbricales and interossei allowing unopposed action of the extensors, and trophic changes leading to loss of elasticity in the joint capsules. These changes are seldom seen in cases where early use of the hand has been allowed, and are most marked where prolonged disuse has been necessary for other lesions. The treatment of the contractures is the same as will be described later under ischæmic contractures. Once we have corrected the contractures, re-education and the use of the hand will in most cases give us a hand with a strong grasp, and once this is attained there is little tendency to recurrence of deformity.



FIG. 225.—Range of movement in fingers which should be obtained before operating to correct palmar flexion of wrist.

2. *Median Nerve.*—Rigidity in the extended position of the interphalangeal joints of the first and sometimes the second finger, with loss of movement in the terminal phalanx of the thumb. Owing to the loss of sensation in the thumb and index finger, there is a tendency on the part of the patient to nurse rather than use the hand. Once the nerve has been sutured, and the patient encouraged and trained to use the hand, little further treatment is necessary until voluntary power of flexion of the terminal phalanges begins to return, when continuous flexion of the index finger will hasten recovery of function.

3. *Musculospiral Nerve.*—Rigidity of the metacarpo-phalangeal joints. Having successfully sutured this nerve, we should await signs of recovery of voluntary extension of the fingers before deciding that active mobilization of these joints is necessary, as this will frequently have been obtained by daily massage and movements before regeneration occurs, a short cock-up splint being used to maintain dorsiflexion of the wrist and abduction of the thumb.

I need not here discuss the treatment of injuries to peripheral nerves, but wish it to be understood that this follows the recognized lines.

I have discussed mobilization and re-education in the use of the fingers first, because I believe it to be a wise preliminary to any further operation directly affecting the hand,

whether that be tendon transplantation to replace function we know to be permanently lost, or correction of deformity of the wrist which we know will further increase the usefulness of the hand. We do not of course expect complete voluntary closure of the hand with a wrist ankylosed in flexion; but unless we have something approaching the range of the normal hand with the wrist in the flexed position, the treatment necessary to obtain movement in the fingers after the position of the wrist has been corrected will tend to a recurrence of the deformity (*Fig.* 225).

Having obtained free passive movement of the joints of the fingers, and as much voluntary control as possible, we can pass to the consideration of the other conditions limiting function.

THE WRIST AND FOREARM.

The deformities and disabilities of the wrist and forearm should be our next consideration (*Fig.* 226). We wish to obtain voluntary extension and flexion of the wrist, and supination and pronation of the forearm; but as this will only be possible in a few of the cases, we aim at the limited movement or ankylosis being in the position most useful to the patient.

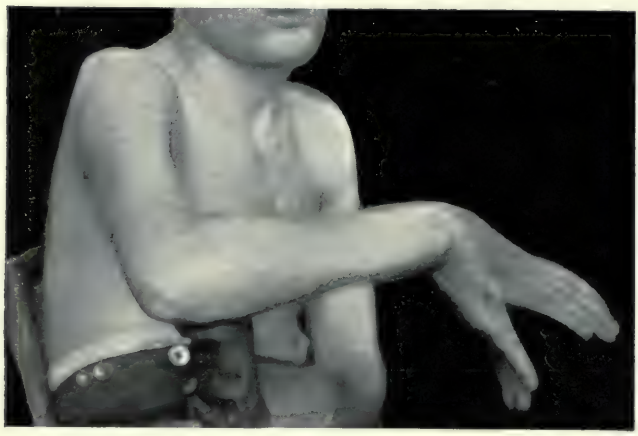


FIG. 226.—Common disabilities of forearm and hand. *Elbow:* Limited movement below right-angle. *Forearm:* Pronated. *Wrist:* Limited movement in flexion. *Fingers:* Stiff in extension.

Let us consider first the pronation and loss of dorsiflexion due to contracture of soft tissues. The previous history of these cases will be usually that of treatment on the internal angular splint, and they will arrive with contracture of elbow, pronation of forearm, the wrist flexed, and the fingers stiff, usually in the extended position. Failing complete restoration of function with treatment in the hydrotherapy, massage, and electrical departments, methods of gradual correction or forced correction under an anæsthetic are still available. The principle of gradual correction is that of overcoming the tension and elasticity of shortened structures by slowly guiding the limb to the desired position. Many splints have been devised for this purpose, but none are necessary if plaster-of-Paris and felt are available.

Having obtained the position of choice, a removable plaster-of-Paris splint should be made to allow movement, and be worn until such time as tendency to re-contracture of the stretched structures is gone. The only sure guide to this is the clinical test which governs the treatment of all scar tissue. The splint is removed first for a short time daily, and use of the limb encouraged. If re-application of the splint is difficult or painful, we must maintain our correction for a further period; but if there is no tendency to recurrence of the deformity, further relaxation may be allowed until the splint is worn at night only, and then entirely dispensed with. Gradual correction will usually be possible where there is limited painless movement; but in cases where there is rigid fixation, one or more anæsthetics and forcible correction will probably be necessary.

Ischæmic Contractures.—Before discussing the cases requiring open operation for their correction, it would be well to describe in detail the correction of ischæmic contractures, which affect mainly the forearm, wrist, and hand. The same principles of treatment apply equally to the contractures from causes which we have already mentioned.

In the severe case the hand is cold and livid, with the wrist flexed and the

fingers contracted; all structures on the flexor aspect of the forearm and hand are shortened, so that such contractile substance as is left in the muscles has no useful sphere of action. We also notice that movement of the wrist towards extension further clenches the interphalangeal joints, while palmar flexion allows their slight relaxation.

Treatment of Ischæmic Contractures (*see Case* 7).—Fully flex the wrist and metacarpo-phalangeal joints; then mould a plaster-of-Paris bandage to fit the palmar surface of the hand and fingers. When this has set, any movement of the wrist towards the straight position will only be possible by the stretching of the structures on the flexor aspect, and this will occur in the order of their tension. Full tension is not a natural condition of any structure of the body, and if we mechanically maintain this condition, nature will assist us in the correction of the deformity by gradual adaptation of the parts to the new conditions. We thus find that in a few days some movement at the wrist is again present, when re-application of the plaster hand-piece will allow further extension of the fingers with the wrist in full palmar flexion.

Having thus corrected the contractures of the hand, a plaster hand-piece is made to fit the hand accurately, the thumb being abducted and slightly forward, the metacarpo-phalangeal joints flexed 20 degrees, and the interphalangeal joints in the extended position. When this is applied to the hand, the wrist can be gradually brought to the straight position by bandaging to an anterior splint. The straight position having been reached, this splint is replaced by a short cock-up splint to obtain full dorsiflexion. The plaster hand-splint serves two useful purposes: first, it prevents contracture of the fingers; in the second place, any pressure applied to it is transmitted to the entire palmar surface of the hand, thus avoiding sores from local pressure.

Having attained full dorsiflexion of the wrist with the fingers extended, the splint may now be removed daily for electrical treatment of the extensor muscles, and as voluntary control of these increases, the clinical test of removing the splint entirely for short periods is again applied and functional use of the hand allowed. The splint is worn at night for some months longer to ensure a permanent result. If, after full extension of the wrist and fingers is complete, stiffness of the metacarpo-phalangeal joints is present, a short cock-up splint and metal finger splints to fix the inter-phalangeal joints are used until movement at the metacarpo-phalangeal joints has been obtained.



FIG. 227.—To show difficulty in writing with ankylosis in full supination.

Open Operation.—In certain cases further mobility and control of the digits can only be obtained after open operation to improve the position or increase the movement of other joints of the limb, and we will take these in the direct order of their effect on our prime object, viz., a useful hand.

1. *Ankylosis of the Wrist.*—This may or may not be associated with loss of movement at the lower radio ulnar joint. If pronation and supination are free, with ankylosis at the radio-carpal joint in the flexed position, we should be careful to confine our operative procedure to the radial side of the joint. A posterior incision, with removal of a small wedge of bone from the dorsal aspect, will give us the dorsiflexed position, which must be maintained by splintage until complete grasp has been obtained, as the treatment

necessary for obtaining this tends to draw the wrist again into flexion. Ankylosis of the wrist in a position of 40 degrees dorsiflexion is no serious disability.

2. *Ankylosis of Wrist and Lower Radio-ulnar Joint.*—If both the joints are ankylosed, before operation we must decide which is the position of choice for the patient, as operation to regain mobility of the joint, though it may be successful, cannot always be relied on.

Although as a rule of treatment full supination is excellent, it is not always the position of choice where ankylosis results. In general, the best position for ankylosis is midway between pronation and supination—i.e., on flexing the elbow, the back of the thumb is brought to the mouth. In the case of a clerk, the position of the hand in writing—that is, a few more degrees pronation—will usually be preferred for the right hand (*Fig.* 227).*

Non-union of Radius and Ulna.—Non-union of one of the bones of the forearm has been remarkably frequent, and I have had three cases in which a flail limb resulted from non-union of both. The hand is attached to, and articulates mainly with, the radius, so that loss of the support of the latter owing to non-union is associated with radial deviation of the hand and considerable weakness of grasp. In the case of non-union of the ulna, the weakness, though present, is less marked, and there is little deformity.

Most ununited fractures of the radius require bone grafting, but some ununited fractures of the lower third of the ulna or of the olecranon show so little disability that this is not necessary. Where the lower fragment of the radius is less than an inch in length, shortening of the ulna to correct radial deviation and allow direct union of the radial fragments gives a good result.

Before operation in these cases, mobility of the hand should be restored, the radial deviation of the hand corrected, and the forearm fixed for a time in the supine position. Unless this is first secured, there will be strain on the graft after operation or union will occur in the position of deformity, which will necessitate further operation for the best result.

With ununited fractures of both bones, a shortening of both to allow direct union, with a bone graft of the ulna to ensure adequate fixation, is the procedure of choice.

We must also remember that where ankylosis of either the superior or inferior radio-ulnar joints is present, any movement of pronation or supination taking place at the site of fracture will be lost if union of the fragments is re-established.

Bone Grafting.—Success depends on: (1) Asepsis; (2) Adequate contact of raw surfaces; (3) Efficient fixation. If there has been severe sepsis, all wounds should be healed for six months, and scar tissue excised where possible.

The preliminary excision of scar tissue serves three useful purposes: (1) It enables us to judge of the probability of grafting bone without the recrudescence of sepsis; (2) It removes tissue of low vitality which will itself tend to necrose and slough after its blood-supply is further reduced; (3) Its removal allows healthy vascular tissue to surround the bone graft.

Care should be taken that the bed for the graft is cut on the surfaces of the fragments that will be in continuity when the limb is in the desired position. As this is usually supination, we should arrange for this position to be maintained from the time the incision is made until the fixation splints or plaster have been applied.

In order to ensure adequate contact and fixation, the graft should be as long as anatomical conditions allow, and should be just wider than the bed which has been cut for it, so that, when wedged into place, it is gripped firmly by the lips of the fragments, and further fixation is not necessary. It should consist of periosteum,

* Where loss of pronation and supination is due to ankylosis of the inferior radio-ulnar joint, the operation lately devised by Captain Baldwin, of San Francisco, is probably the best. His operation consists of the removal of a portion of the lower third of the ulna, in order to obtain a false joint which allows voluntary pronation and supination.

cortex, and endosteum, and be of sufficient strength itself to withstand the strain of function when union is complete.

Fixation by means of splints should usually be maintained continuously for a period of three months.

THE ELBOW-JOINT.

The conformation of the articular surfaces of the elbow-joint allows of movement only in the antero-posterior direction. The superior radio-ulnar joint communicates with it, and is necessarily involved in general arthritis of the joint. If the radio-humeral or radio-ulnar joint is ankylosed, pronation and supination are not possible (*Fig.* 228). The muscles producing these movements are not adapted for controlling lateral movements, so that often the best result to be obtained after severe wounds involving the joint will be the greatest degree of movement in the antero-posterior direction, with stability on lateral strain. Cases will arise where free flexion and extension is essential for the patient, and if lateral stability could be assured, this would be best for all; but for the man who depends on the strength of his arm for his livelihood, an ankylosed joint in the position of choice should, in my opinion, only be subjected to operation when the facts have been laid clearly before the patient. My experience has been, that if you are to guarantee free movement of the joint, so much bone must be resected that lateral mobility will interfere with the strength of the limb (*Fig.* 229). One knows that in the acute stages free removal of bone may be necessary to save life or limb; but recent literature advocating free removal of bone as a routine measure in gunshot wounds of the elbow is not justified by the end-results which find their way to military orthopædic hospitals. It has in my experience been necessary to operate more frequently to increase the stability than the mobility of the joint.



FIG. 228.—Showing range of movement obtained by conservative treatment.



FIG. 229.—Same patient as *Fig.* 228.

The flail elbow-joint without voluntary control and with wide separation of the bone surfaces is one of the most difficult problems to deal with surgically, and often ends in fixation by external splintage. Stability of the elbow-joint is dependent more on the articulation with the ulna than the radius, and a good functional result is often

seen with absence of the external condyle. One does see cases of excision which result in fair control and mobility, but this result seems to be more assured by an operation of choice when the question of sepsis has been eliminated. So many cases of apparently hopeless destruction end in fair movement if treated on conservative lines, that bone should only be removed to meet the immediate necessity of the case.



FIG. 230.—Photograph to illustrate ankylosis of elbow in extension with pronation of forearm. Points to be guarded against in prolonged treatment in Thomas arm splint.

Let us consider, then, the conservative treatment of wounds of the arm with a view to obtaining the maximum movement of the elbow-joint, or, if ankylosis is inevitable, the best position for this (*Fig.* 230).

The essential treatment will be rest, often for some months, and the position of rest must be guided in the first place by the condition of the wounds. For efficient treatment of these, full extension and fixation in the Thomas arm splint is commonly used until the acute sepsis has been controlled or the fracture has begun to show signs of union, when the arm should be gradually flexed, supination being assured from the beginning. If the fully flexed position with supination could be obtained and maintained until the conditions demanding rest no longer existed, a large number of cases would not require such prolonged treatment in hospitals in this country. Cases with pronation of the forearm and limited movement below a right angle are so common, that every effort should be made to guard against them as early as possible. Once we have secured full supination and flexion at the elbow-joint, any movement which results will be in the best position, and gravity and function will both aid in its increase. In the later stages, considerable force will often be required to obtain this position, and it will usually be safer to use gradual means, and if an anæsthetic is necessary, not to attempt too much at one time, because of the risk of fracture of the olecranon and the recrudescence of sepsis. We then wait until all sign of reaction has gone before applying the clinical test which will decide whether it is now safe to allow movement. When the biceps—previously weak—has recovered its tone, and there is no peri-articular thickening or tenderness, the collar and cuff (*Fig.* 231) which maintain the position are relaxed, allowing limited extension. If the patient can voluntarily resume the position of previous fixation, further liberty is allowed; and when movement from full flexion to a right angle is free, and the patient has learned to use the joint again, function and gravity are now both allies in obtaining further increase of movement.

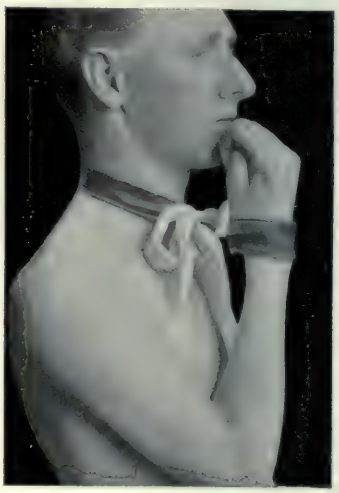


FIG. 231.—Showing Thomas's collar and cuff to maintain flexure of elbow and supination of forearm.

Where ankylosis is to be expected, the position of choice—usually an angle of 100 degrees, with the forearm midway between pronation

and supination—should be maintained until the ankylosis is sound. Special cases will arise where another position is desired.

Bone Blocking Flexion.—This should be removed, by operation if necessary, as soon as conditions permit, and the acutely flexed position obtained.

Myositis Ossificans.—The history is usually that of movement gradually becoming more limited with use. *X* rays show new bone formation on the flexor aspect, frequently in the substance of the brachialis anticus.

Treatment.—The elbow should be kept at rest in flexion until ossification is complete, when movements can be gradually recommenced. Any forced passive movements will only aggravate the condition, and any operation for its removal before this stage is reached is doomed to failure.

THE SHOULDER-JOINT.

Wounds involving the shoulder-joint require our special attention at an early stage to secure a good result. They are frequently complicated by paralysis of the deltoid and much laceration of the soft parts. In some cases two or three inches of the upper end of the humerus have been removed. The end-result of these cases is usually either a flail limb without power of abduction (*Fig.* 232), or ankylosis in the adducted position, requiring further operation to get a useful range of movement.



FIG. 232.—Showing common disability following excision of upper end of humerus.

In this joint, perhaps more than any other, the cicatrization of scar tissue, so often responsible for grave and irreparable deformity, may in certain cases, if carefully guided, play an important part in the restoration of function.

As soon as the acute sepsis is past, the limb should be fixed with the shoulder abducted 70 degrees, and with the elbow-joint just in front of the coronal plane of the body, so that when flexed the palm of the hand easily reaches the mouth. Plaster-of-Paris, with windows cut to allow of dressing, should be applied so as to keep the upper end of the humerus in close proximity to the glenoid cavity. This position is maintained until bony or short fibrous ankylosis results, when, the sterno-clavicular joint being the centre of motion, an almost complete range of abduction and adduction may be obtained.

The abducted position of the shoulder is also indicated in all cases where this movement is likely to be limited, either by new bone formation in the neighbourhood of the great tuberosity, or fracture of the acromion process. It also allows relaxation and recovery of a weakened deltoid, and prevents contracture of the axillary folds, which is so common after general inflammation of the upper limb.

Where the muscles controlling the scapula are paralyzed, postural relaxation with electrical treatment should be persevered with, unless recovery is impossible from the nature of the injury, when a shoulder-brace to control its movement will allow a more powerful use of the limb.

Where the scapula is fixed to the ribs as the result of severe injury, movement at the shoulder-joint will vary with the degree of its rotation. Operation to alter this will not as a rule be indicated, as, with the scapula in its position of rest, abduction of the shoulder to a right angle is still possible.

THE SURGERY OF NERVES AND TENDONS IN RELATION TO JOINTS.

Gunshot wounds often result in the loss or destruction of several inches of the main nerves, and the possibility of suture is frequently dependent on our being able to obtain the necessary relaxation of the joints of the limb by posture. The positions usually required are flexion of the wrist and elbow, with or without pronation of the forearm, and adduction of the shoulder. These positions, if present, should not be altered until suture of the nerves is assured, and if possible they should be obtained before this is undertaken. After suture is completed, the position of the joints should be maintained for two weeks before gradual, and one month before forcible, alteration of their position is allowed.

Where it has not been possible to obtain direct continuity of the nerves, there still remains nerve crossing, nerve grafting, or tendon transplantation to fall back upon. My own experience of the first two has been unfavourable, and I now depend entirely on the last.

One of the most important factors for success in tendon transplantation is the condition of the joints directly affected.

I have recommended nerve suture as the prime consideration in the treatment of the joints of the upper extremity, and have no hesitation in emphasizing the importance of tendon transplantation as the final operation to be undertaken in the treatment of disabilities of these joints. For it to be successful, we must have strong healthy muscles, and these will only be available if the joints they control have allowed of their free development.

DETAILS OF CASES.

It has only been possible in a short article to give a bare outline of so important a subject, and I therefore append a detailed account of nine cases, with illustrations, in the hope that they may help to demonstrate the points on which stress has been laid.

Case 1.—Pte. H. **Gunshot wound of left arm,** June, 1916.

Condition on Admission, May, 1917.—Ununited fracture just above elbow. Ankylosis of elbow-joint. Lesion of musculospiral and ulnar nerves; flexion and rigidity of wrist and fingers.

June 6, operation. Musculospiral nerve: separation 2 in.: suture allowed by flexion at site of fracture. Ulnar nerve: transferred to flexor aspect of joint, and also sutured. Oct. 23, fixation of ununited fracture by bone graft; plaster-of-Paris fixation of shoulder and elbow. Nov. 27, correction of contracture of hand by graduated splintage. Jan. 18, 1918, electrical treatment and massage of all muscles of limb commenced.

Note.—Had the nerve injury not been so severe, the treatment of the contracture of the hand deformity with temporary fixation of the elbow in plaster would have preceded the bone graft.

Failing recovery in these nerves, no operation of tendon transplantation would be undertaken until the full potentialities of recovery have been obtained in the muscles supplied by the median nerve. It might then be advisable to ankylose the wrist in dorsiflexion as a

preliminary, in order to enable us to use the limited muscles available to the best advantage.

Case 2.—L.-Cpl. D. **Gunshot wound of wrist, Jan. 7, 1917. Wounds healed March 10.**



FIG. 233.—*Case* 2. Showing condition on admission, April 2. Wrist ankylosed in flexion; forearm pronated; metacarpo-phalangeal joints rigid in extension.



FIG. 234.—*Case* 2. Showing fixation in plaster after forcible supination and partial dorsiflexion of wrist.



FIG. 235.—*Case* 2. Aug. 10. Showing use of short cock-up splint to maintain dorsiflexion of wrist while movement of fingers is obtained.

Condition on Admission, April 2.—Ankylosed wrist in flexed position (*Fig.* 233); forearm allowing 10 degrees movement in prone position. Metacarpo-phalangeal joints rigid in extension,



FIG. 236.—*Case* 2. Sept 9. Showing range of movement obtained.

due to sepsis and involvement of extensor tendons on dorsum of wrist.

April 11, anæsthetic; flexion of metacarpo-phalangeal joints; fixation in plaster-of-Paris. When swelling and reaction subsided, gradual flexion of interphalangeal joints gave the necessary stretching of structures on the extensor aspect. Flexion of metacarpo-phalangeal joints maintained for four weeks, then free use of the fingers encouraged. June 4, cuneiform osteotomy, radiocarpal joint, to allow of 45 degrees dorsiflexion of wrist. Fixation in supination and plaster-of-Paris (*Fig.* 234). Aug. 10, plaster-of-Paris removed; short cock-up splint applied to allow more free use of the hand (*Fig.* 235). Sept. 9, photograph shows movement obtained (*Fig.* 236).

Case 3.—Pte. H. **Gunshot wound of left forearm, Oct. 26, 1915.**

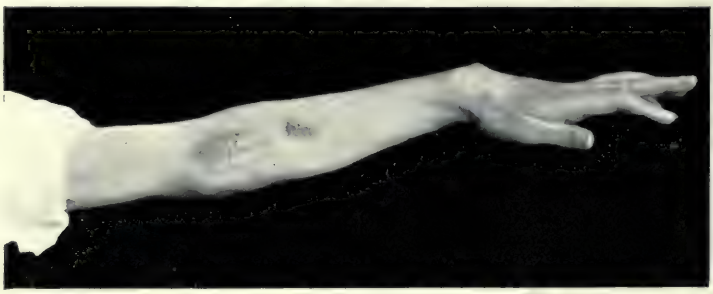


FIG. 237.—*Case* 3. Photograph to show radial deviation of hand and deformity of the wrist due to ununited fracture of radius and scar-contracture.



FIG. 238.—*Case* 3. Showing plaster hand-piece and short cock-up splint used for gradual correction of deformity of the wrist.

Condition on Admission, Dec. 14, 1916.—Ununited fracture of radius, with radial deviation of hand, and scar contracture of structures on flexor aspect of forearm causing anterior subluxation at wrist-joint; loss of dorsiflexion and pronation of forearm (*Fig.* 237).

Dorsiflexion of wrist obtained by graduated splintage (*Fig.* 238). March 6, 1917, anæsthetic; supination of forearm and correction of radial deviation of hand. Fixation in plaster. April 7, bone graft of radius; fixation in plaster-of-Paris for three months, allowing free use of fingers. Six months after the last operation a strong, useful hand resulted, with all movements controlled.

Case 4.—Pte. B. **Flail elbow** (*Figs.* 239, 240).
X ray shows absence of lower end of humerus, head of radius, and upper end of ulna. Moulded leather splint to allow use of limb.



FIG. 239.—*Case* 4. Showing flail elbow following early excision.



FIG. 240.—*Case* 4. Fixation of elbow by external splinting, to allow use of hand.



FIG. 241.—*Case* 5. Showing new bone formation in front of elbow, limiting flexion.



FIG. 242.—*Case* 5. Showing range of movement obtained after treatment in acute flexion.

Case 5.—Pte. J. R. **Gunshot wound of right elbow**, Oct. 7, 1915.

June 5, 1916, elbow-joint was excised. In splint two weeks, sling five weeks. Massage and passive movement commenced seven days after operation.

Condition on Admission, Aug. 12.—Twenty degrees passive movement at an angle of 140 degrees. Pain on forcing movement. *X* rays show new bone formation in front of joint (*Fig.* 241).

Aug. 16, elbow flexed to 48 degrees under anæsthetic. Collar and cuff applied. Oct. 4, has 15 degrees movement to acute flexion. Arm to be gradually dropped. Nov. 20, photograph shows range of movement on discharge five months later (*Fig.* 242).

Case 6.—Pte. P. **Shrapnel wound of left elbow, Dec. 12, 1916.**

Four operations for removal of bone.

Condition on Admission, April 2, 1917 (*Fig* 243).—Discharging sinus; fusiform swelling of joint. Arm held with elbow at angle of 160 degrees; 45 degrees passive movement, no voluntary control. Forearm in pronation; attempt to supinate painful. Unable to dorsiflex wrist. Fingers rigid.

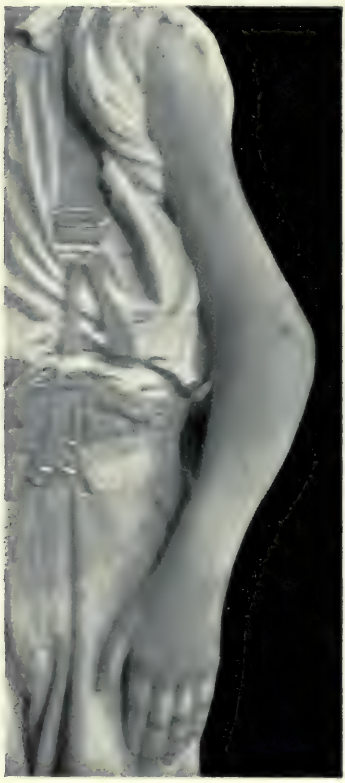


FIG. 243.—*Case* 6. Condition on admission.



FIG. 244.—*Case* 6. Showing use of Jones's elbow splint to gradually supinate forearm and flex elbow.



FIG. 245.—*Case* 6. Showing flexion and range of movement obtained eight months after admission.

Gradual supination of forearm and flexion of elbow with Jones's elbow splint, with wrist gradually dorsiflexed on short cock-up splint (*Fig.* 244). Dec. 3, photograph shows voluntary movement obtained (*Fig.* 245).

Case 7.—Pte. L. **Ischæmic contracture. Gunshot wound of right arm, Feb. 5, 1915.**



FIG. 246.—*Case* 7. Ischæmic contracture following gunshot wound of right arm. Condition on admission.

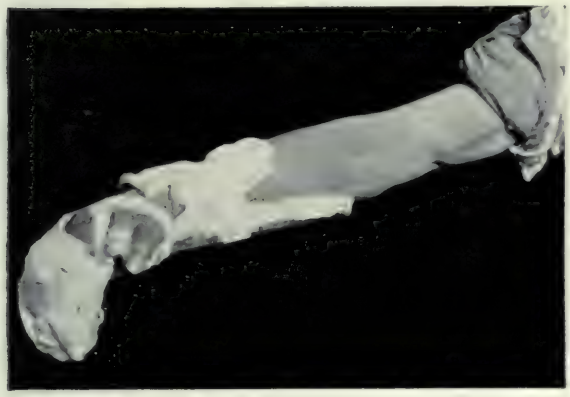


FIG. 247.—*Case* 7. Showing method of gradual correction of contractures by plaster hand-piece and anterior splint.



FIG. 249.—*Case* 7. Showing short metal splints used to maintain extension of the interphalangeal joints while movement at the metacarpo-phalangeal joints is obtained.



FIG. 248.—*Case* 7. Showing complete correction of contractures by plaster hand-piece and short cock-up splint.



FIG. 250.—*Case* 7. Showing range of voluntary movement obtained nine months after admission.

Condition on Admission, June 26, 1916.—Right hand livid and contracted; wrist flexed; metacarpo-phalangeal joints hyperextended; phalanges in intense flexion (*Fig.* 246).

July 17, gradual correction of contracture by plaster-of-Paris hand-piece and anterior splint (*Fig.* 247). Nov. 10, complete dorsiflexion obtained by plaster-of-Paris hand-piece and short cock-up splint (*Fig.* 248). Extension of interphalangeal joints maintained while flexion of metacarpo-phalangeal joints is obtained (*Fig.* 249). March 1, 1917, photographs show the degree of voluntary opening and closing of the hand obtained (*Fig.* 250).

Case 8.—Bugler E. **Gunshot wound of left shoulder,** Sept. 14, 1916.
Condition on Admission, Nov. 7.—*X* rays show much swelling and pain (*Fig.* 251), with discharging sinus. No involvement of main nerves.

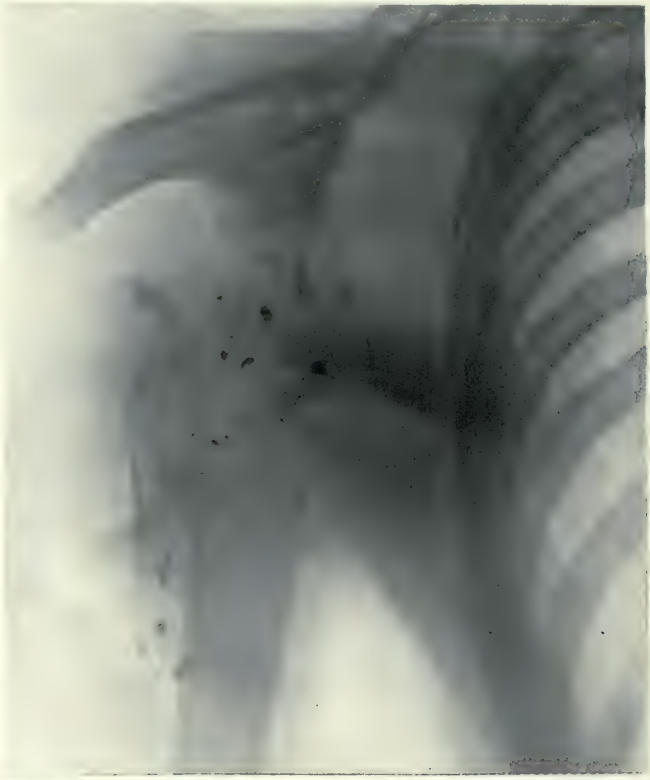


FIG. 251.—*Case* 8. Gunshot wound of shoulder. Condition on admission seven weeks later, showing absence of upper end of humerus.



FIG. 252.—*Case* 8. Showing plaster fixation with a view to ankylosis of shoulder in the abducted position.

Nov. 25, arm fixed in abduction; plaster-of-Paris, with window for dressing (*Fig.* 252). Jan. 11, 1917, removal of sequestrum. *X* rays show position of ankylosis obtained (*Fig.* 253). Oct. 8, photograph shows range of movement obtained (*Fig.* 254).



FIG. 253.—*Case* 8. Showing ankylosis of humerus and scapula.

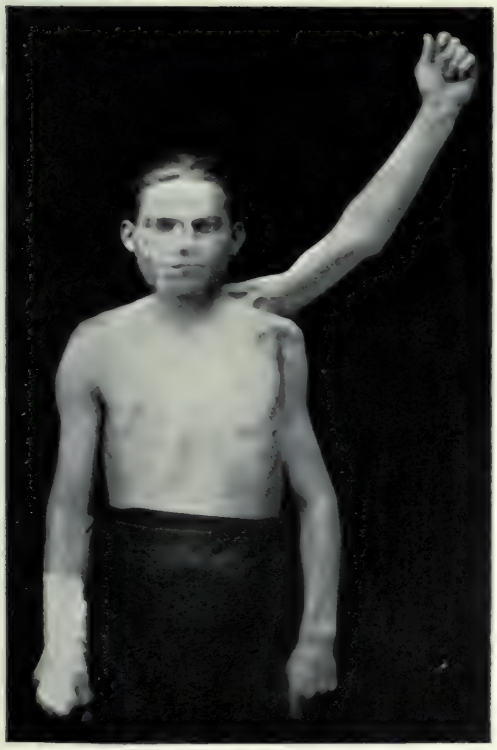


FIG. 254.—*Case* 8. Showing range of scapular movement obtained.



FIG. 255.—*Case* 9. Gunshot wound of shoulder, showing condition on admission three weeks after injury.

Case 9.—**Pte. E. Gunshot wound of left shoulder, May 20, 1917 (*Fig.* 255).**

***Condition on Admission*, June 12.—*X* rays show absence of upper third of humerus, head of scapula, acromion process, and outer portion of clavicle (*Fig.* 256).**

Aug. 21, photograph shows scar tissue contracted to thin line (*Fig.* 257).
This patient is now able to raise his arm from the splint voluntarily (*Fig.* 258). The ankylosis is one of scar tissue between the upper end of the humerus and shoulder girdle.

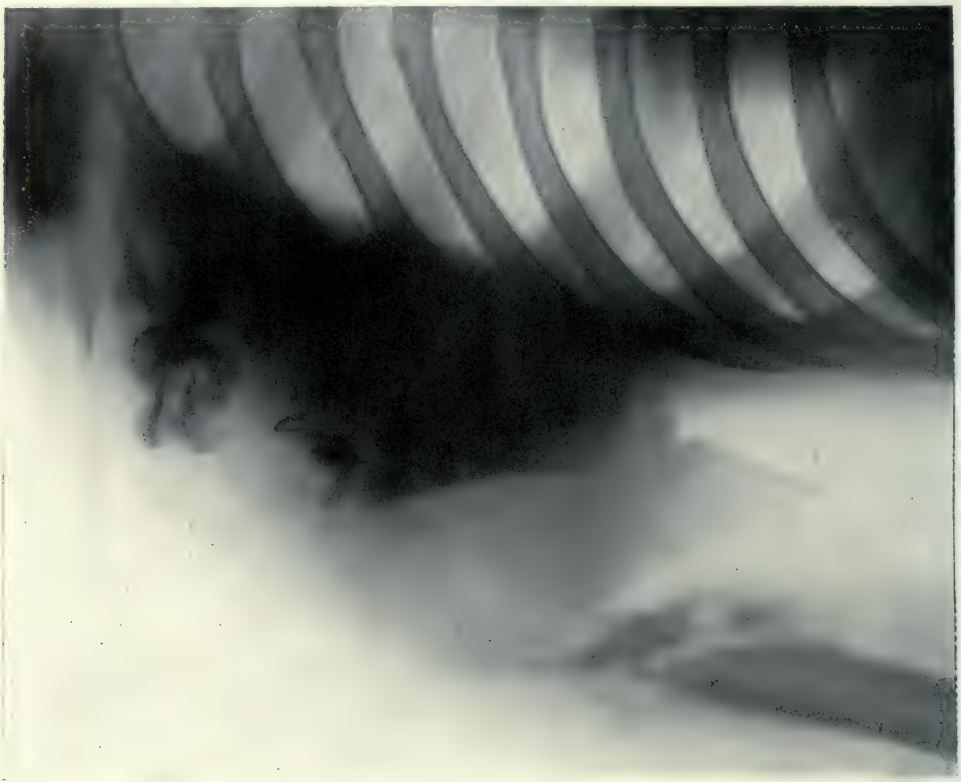


FIG. 256.—*Case* 9. Showing absence of upper third of humerus, head of scapula, acromion process, and outer portion of clavicle.



FIG. 257. *Case* 9. Showing position of fixation and contracture of scar.



FIG. 258.—*Case* 9. Showing approximation of shaft of humerus to shoulder girdle nine months after injury.

THE RESULTS OF PRIMARY EXCISION FOR WOUNDS OF THE ELBOW-JOINT.

By Captain A. EISDELL MOORE, R.A.M.C.

During the last year a considerable number of wounds in the region of the elbow, with fractures involving the joint, have been treated by a primary excision of the elbow-joint at the casualty clearing station. As a result, the staffs of the orthopædic hospitals are being called upon to treat an increasing number of flail elbow-joints, a disability which causes great impairment of function, and which is difficult to correct satisfactorily.

The following remarks are based on eleven consecutive cases (as set out in table form on the following page) recently treated at the Bristol orthopædic centre, and which had had primary excision of the elbow-joint performed at the front. It is doubtful if in more than two patients (*Cases* 9 and 10, *Fig.* 266) the result can undeniably be called good. One appreciates that because this is an orthopædic centre the cases seen probably include the more unsatisfactory results, still the publishing of them may be of use to the surgeon at the C.C.S.



Fig. 259.—*Case* 1. Pte. B. Extensive primary excision.

The Relation between the Amount of Bone Removed and the Subsequent Functional Result.—In classifying these cases one realizes at once that the final functional result depends mainly on the amount of bone that has been removed. Colonel Mansell Moullin[1] advocates primary excision provided sufficient bone is removed, and advises a thorough removal of the articular ends of the humerus, radius, and ulna, whilst Major Swan[2] and Captain Sheppard[3] advocate a less extensive operation; the following cases support fully the latter opinion.

Of the eleven cases given, ten have flail elbows to a greater or lesser degree, and the uselessness of the limb is—if the length of time from the original wound be taken into account—in almost direct proportion to the amount of bone removed. The cases are arranged according to the extent of the operation, and it will be noted that as the amount of bone removed decreases so does the functional result improve. Thus *Case* 1, *Fig.* 259, shows a gap of 4½ inches between the cut ends of the humerus, and radius and ulna. Undoubtedly some of this is due to the stretching of the soft parts; still, the original removal of bone must have been very extensive. Naturally the elbow-joint, as such, is useless.

Case 11, *Fig.* 267, shows an ankylosis—the result of removing too little bone—so from this series of eleven, one would gather that the tendency in this operation is at present to remove too much bone rather than too little.

TABLE SHOWING THE RESULTS OF ELEVEN CASES OF

Case	Name	Type of Excision	Gap by X-rays	Time after Wound when Report made	Time taken for Wound to heal	Resulting Joint	Passive Movement			
							Flexion	Extension	Lateral Internal	Lateral External
1	Pte. B., *Fig.* 259	Humerus: lower end Radius: head and tubercle Ulna: olecranon	4½ in.	6 mths.	2 mths.	Flail	Full	210°	90°	90°
2	Sgt. M.	Humerus: lower end Radius: head Ulna: olecranon	2 in.	3 mths.	2½ mths.	Flail	Full	210°	50°	70°
3	Pte. S., *Figs.* 260, 261	Humerus: lower end Radius: head Ulna: olecranon	2 in.	8 mths.	1½ mths.	Flail	Full	190°	60°	90°
4	Lt. J., *Figs.* 262, 263, 264	Humerus: lower end Radius: head Ulna: olecranon	2 in.	10 mths.	1 mth.	Flail	Full	200°	70°	90°
5	Pte. S.	Humerus: lower end Radius: untouched Ulna: olecranon	1⅛ in.	5 mths.	2 mths.	Flail	Full	190°	90°	90°
6	Pte. P., *Fig.* 265	Humerus: lower end Radius: untouched Ulna: untouched	¾ in.	9 mths.	6 mths.	Flail	Full	160°	60°	90°
7	Rfm. A.	Humerus: lower end Radius: untouched Ulna: untouched	¾ in.	5 mths.	3 mths.	Flail	Full	210°	90°	90°
8	Pte. B.	Humerus: lower end; much new bone formed Radius: untouched Ulna: untouched	⅝ in.	5 mths.	1½ mths.	Flail	Full	200°	60°	20°
9	Pte. B.	Humerus: below epicondyle Radius: artic. surface Ulna: olecranon process	in.	9 mths.	6 mths.	Weak	Full	120°	Nil	30°
10	Pensnr. D. *Fig.* 266	Humerus: above epicondyle Radius: untouched Ulna: untouched	1 in.	7 mths.	4 mths.	Weak	Full	200°	30°	30°
11	Bdr. E., *Fig.* 267	Humerus: artic. surface Radius: artic. surface Ulna: artic. surface	—	8 mths.	7 mths.	Ankylosed	Nil	Nil	Nil	Nil

Case 12, Pte. P. (*Figs.* 268, 269, 270), is one in which arthroplasty was performed eleven

RIMARY EXCISION FOR WOUNDS OF THE ELBOW-JOINT.

ACTIVE OVEMENT	HAND GRIP	REMARKS
None	Good	Forearm muscles arising from humerus formed new attachment to forearm bones, and flexion action of supinator thus lost.
None	Very weak	
ctive to 70°	Good	Supported in plaster in early treatment. Marked overriding of bones in voluntary flexion.
ctive to 90°	Fair	Gap between ends of bones decreased rapidly on wearing support.
None	Fair	Complicated by ulnar paralysis. *Capsulorrhaphy* performed 5 months after wound. 7 months after wound had 30° voluntary flexion, and lateral mobility decreased to 30° internally and 30° externally.
ctive to 110°	Fair	Complicated by ulnar paralysis. *Capsulorrhaphy* performed with ulnar suture 9 months after wound. 12 months after wound active flexion to 60°, lateral mobility decreased to 10° internally and 20° externally. Some grating on extension.
Good power	Good	
None	Fair	After support for 2 months (5 months after wound till 7 months after wound) voluntary flexion to 60° returned.
omplete, but with difficulty	Good	Supported in plaster in early treatment. In voluntary flexion arm supinated first and then flexed, mostly by means of supinator longus.
ctive to 60°	Good	Marked tendency for humerus to override outwards.
Nil	Good	Treated in a straight Thomas splint after primary excision. Operation 8 months after wound to repair ulnar nerve. Excess of callus removed and arm flexed. No attempt at arthroplasty, this being left till later date.

ionths after the wound, and is included for comparison with the above primary excisions.

Method of Limited Excision.—Of course it is impossible to lay down definite rules for any war surgery, and the amount of bone removed must depend largely on the amount of comminution. Yet I would urge that the lines for excision follow Captain Sheppard's method as far as possible; that is to say, the lower end of the humerus is rounded off above the epicondyles, and the radius and ulna are preserved intact. If comminution extends beyond this line there is a great temptation to remove more bone; but it is better to leave this as far as possible, and to cover in the ends of the comminuted bones with a muscle-fascia flap in the same way as is done in performing an arthroplasty. A comparison between *Cases* 1 (*Fig.* 259) and 6 (*Fig.* 265) brings out this point; all comminuted bone was removed in *Case* 1, whilst in *Case* 6 the lower end of the humerus, although badly broken, was left *in situ*, and though it forms no ideal articular surface, the functional result obtained is much better than with *Case* 1. *Case* 4 (*Figs.* 262, 263, 264), where the *x*-ray showing the original injury is available, is also instructive. A piece of shell is seen lying in the comminuted



FIG. 260.—*Case* 3. Pte. S. Bones separated in extension.



FIG. 261.—*Case* 3. Pte. S. Bones overriding before flexion occurs.

lower end of the humerus. The excision performed included the humerus, the radius, and ulna, and the result is not good. One feels that had the operation been limited to the removal of the lower end of the humerus, the patient would have had a much more serviceable joint.

Relation of the Extensive Operation to Sepsis.—It has been argued that wide excision is the best treatment from the point of view of controlling sepsis. In this series only one case healed within a month, the others give an average of over three months. This is not rapid healing; but certainly the more bone removed the more speedy is the first closure of the wound. This, however, by no means compensates for the resulting loss of function.

Again, one cannot but feel that there is a definite risk in the extensive opening up of raw bone surfaces in the presence of sepsis, and also that the sepsis may in itself defeat the real purpose for which primary excision is performed, by stimulating the osteogenetic power of the bone. A glance at the radiogram of *Case* 11 (*Fig.* 267)

shows the large amount of new bone thrown out. It is probable that if an excision of the same extent as was done in this case primarily, in the presence of sepsis, had been done later when the sepsis had cleared up, a movable joint would have been obtained.

The Ability to Preserve Muscular Attachments in the Limited Excision.—In regard to the preservation of muscular attachments, the importance of leaving the



FIG. 262.—*Case* 4. Lt. J. Before operation.



FIG. 263.—*Case* 4. Lt. J. During treatment after primary excision. Drainage tube *in situ*.

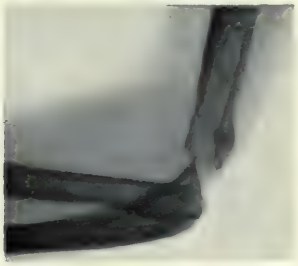


FIG. 264.—*Case* 4. Lt. J. After treatment by support.

triceps has been noted in many papers; but less attention has been paid to the equally important point of leaving the origin of the supinator longus. *Case* 9 provides a good example. The patient in flexing his elbow uses his supinator longus considerably more than his biceps. To preserve the origin of the supinator longus is of increased importance, of course, if the radius is badly comminuted at its upper end. Considering that the origin of the supinator longus extends high up the external supra-condylar ridge, it is seldom necessary to interfere with this muscle at all in dealing with a wound limited to the elbow-joint. Another case (*Case* 1) where the origin of the muscle has been removed shows also that it is useless as a flexor of the elbow in its new attachment to the radius, although the patient has a strong wrist and hand from the new attachment of flexors and extensors of the wrist and fingers.



FIG. 265.—*Case* 6. Pte. P. Comminuted lower end of humerus has been preserved.

The Resulting Flail Joint.—An analysis of the ten cases which developed flail-joints after primary excisions shows that:—

1. Passive movement is usually possible from full flexion to about 20 degrees over full extension, and lateral mobility varies from 20 degrees externally only to 90 degrees both internally and externally. This excessive lateral movement is a great disability, the forearm tending to drop downwards when the upper arm is abducted, and so practically preventing any use being made of the shoulder-joint.

2. Active movement is usually possible, although weak, but in a certain number

of cases is quite absent. Active movement is the standard of success, and unless active movement is good, and lateral mobility slight, there is no doubt that an elbow ankylosed in good position gives the patient a great deal more serviceable limb.



FIG. 266.—*Case* 10. Pensr. D. Limited excision. Useful joint.

The resulting joint is also greatly dependent upon the immediate post-operative treatment. The forearm must be supported efficiently to prevent the fibrous union from becoming stretched, and it is noteworthy that in *Cases* 1 and 2, where no active movement was possible six months and three months respectively after operation, no attention had been paid to the support of the forearm, and in some of the other cases the weight of the forearm had been taken by the young fibrous tissue far too soon.

This stretching of the fibrous union also accounts for a condition of overriding of the bones when voluntary flexion returns. The humerus overrides the forearm bones on their outer side, and in flexion the arm is apparently shortened before the movement of flexion occurs by contraction of the long flexors of the forearm. This "taking in of the slack of the joint" is well seen in *Figs.* 260 and 261. This patient had a lucky formation of a periosteal bone spur on the inner side of the humerus, and this acted as a pivot which gave support to the ulna in flexion. He had a very useful arm.

The Treatment of the Flail Joint.—This is the problem that most concerns the surgeon at the orthopædic hospital. The joint has become flail as a result of: (1) Too wide a removal of bone; (2) Subsequent stretching of the soft tissues.

The former cannot be remedied (those extensive enough for bone-grafting to be considered are classed as flail limbs, not flail joints); but the result of stretching of the soft tissues may be considerably helped by:—

A. Support.—In all cases the weight of the forearm must be taken from the soft tissues joining the humerus and forearm. This can be done by a simple forearm sling bringing the wrist well up towards the neck, or the arm may be put up in full flexion in plaster-of-Paris for a month or six weeks, to allow contraction of the stretched soft tissues. The actual improvement possible, even after there has been stretching, is seen in *Figs.* 263 and 264, where a $2\frac{1}{2}$-inch gap was reduced to half an inch by this means alone.

B. Massage, Electricity, and Hydrotherapy, to improve the tone of the stretched tissues.

C. Operation.—In *Cases* 5 and 6 in this series an attempt was made to reef in the excess of new fibrous tissue that was allowing the excessive play at the elbow. A simple capsulorrhaphy through a posterior incision

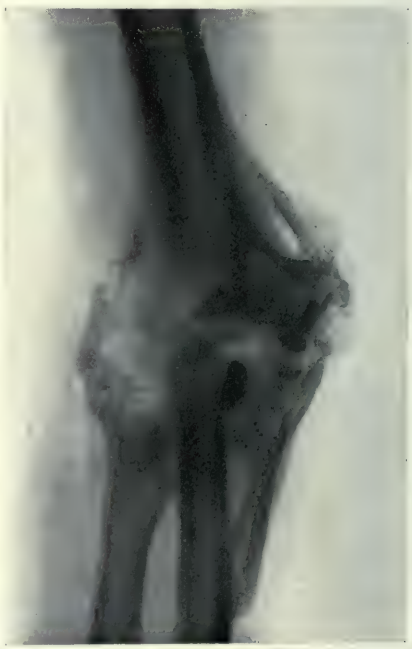


FIG. 267.—*Case* 11. Bdr. E. Ankylosis.

was performed, and the new 'capsule' reefed posteriorly and at both sides. There was some improvement in the degree of lateral mobility in each case, but one of the patients (*Case* 6, *Fig.* 265) suffered some subsequent inconvenience from a 'grating' of the two bone surfaces thus brought closer together. I do not think this would have occurred had the ends of the bone at the primary excision been covered by muscle-fascia flaps.

D. Mechanical Treatment.—The functional report on the above cases was made before any mechanical support was provided. The provision of a light aluminium support consisting of two lateral pieces hinged at the elbow-joint and restraining lateral mobility, whilst allowing flexion and extension, considerably aids voluntary movement.

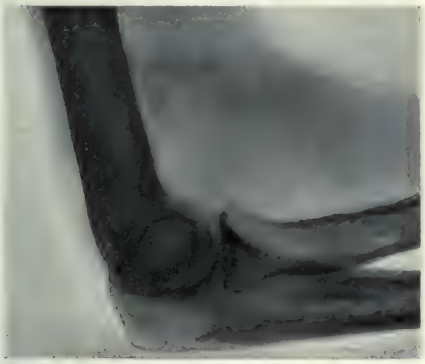


FIG. 268.—*Case* 12. Pte. P. Showing ankylosis before operation.



FIG. 269.—*Case* 12. Pte. P. Showing extension obtained after limited arthroplasty.

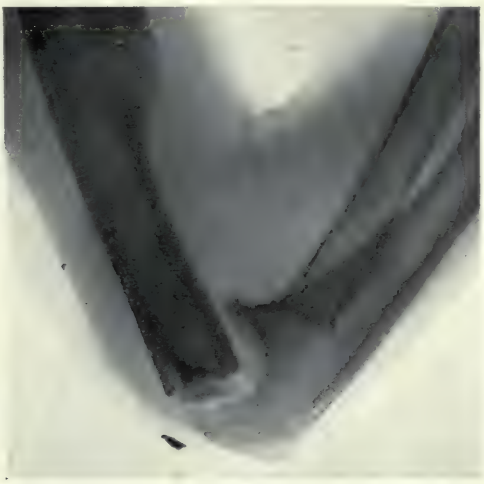


FIG. 270.—*Case* 12. Pte. P. Showing flexion obtained after limited arthroplasty.

Comparison of Results of Primary Excision with a Case of Arthroplasty for Ankylosis.—In comparison with the above series, I would quote the following case

of arthroplasty of the elbow performed for ankylosis after a gunshot wound. *Case* 12 (*Figs.* 268, 269, 270). This patient had very little comminution of the bone, but a septic arthritis, and injury to both median and ulnar nerves. Nerve repair was performed six months after the wound, and a partial arthroplasty five months later. The arthroplasty consisted in removing the external condyle of the humerus piecemeal, and the articular surface of the head of the radius, then dislocating the joint outwards, and sawing the humerus off just below the epicondyles. This method allows the bone to be removed through a small incision, with no injury to the triceps tendons, and only a little weakening of the external aspect of the joint. The sigmoid cavity of the ulna was preserved, and the lower end of the humerus rounded off and covered by a flap of muscle-fascia from the extensor origin. The joint was kept in full flexion for three weeks without any attempt at movement. At the end of this time there were 40 degrees passive movement without pain, and six weeks after the operation there is 75 degrees voluntary movement, painless, and only 5 degrees lateral mobility internally and none externally.

CONCLUSIONS.

1. Extensive primary excision must result in a flail joint.
2. Limited excision is satisfactory.
3. If the bone is comminuted, muscle-fascia flap should be carried in to cover comminuted bone as is done in arthroplasty.
4. Post-operative support of forearm is essential.
5. Rest is more important than early movement.
6. Capsulorrhaphy in certain chosen cases of flail elbow does good.

REFERENCES.

[1] Col. Mansell Moullin, *Brit. Med. Jour.*, 1917, Nov. 3.
[2] Major Jocelyn Swan, *Brit. Med. Jour.*, 1918, Jan. 26.
[3] Capt. Moir Sheppard, *Brit. Med. Jour.*, 1918, Feb. 2.

THE STRUCTURE, FORMS, AND CONDITIONS OF THE ENDS OF DIVIDED NERVES:

WITH A NOTE ON REGENERATION NEUROMATA.

By Major EDRED M. CORNER, R.A.M.C.(T.)

(A Report to the Medical Research Committee.)

The first steps in any undertaking should be to prepare the ground carefully, in order to form a sure foundation for subsequent work which may be built upon it. This is the object of the present preliminary report on the nerve endings in amputation stumps, and upon it the writer hopes to build a strong pathological and clinical superstructure.

When a nerve trunk is divided, it retracts—provided it has not previously been torn from its bed, as may easily be done. Of the two kinds of tissue thus divided: (1) The divided nerve fibres commence to degenerate and afterwards regenerate, undergoing two changes; and (2) The divided connective tissue (the endoneurium, perineurium, and epineurium) commences at once to repair, and, undergoing but one change, gets a considerable start as compared with the nerves. Consequently, in the early stages the end bulbs of a divided nerve consist very largely of fibrous tissue. Into that bulb of scar tissue the nerve fibres grow. The central part of the nerve bulb is formed from the repairing inner coats of the nerve (the endoneurium and the perineurium). Its outer and circumferential parts are largely formed from the outer coat (the epineurium). This connective-tissue bulb has partly ceased to contract by the time the nerve fibres grow into it, by reason of its early start, and it offers a substantial buffer to the regenerating nerve. The varying densities produced by the growth and contraction of this fibrous tissue give ever-varying patterns of the nerve fibres in it: some have been observed in serial sections to be completely turned round, apparently by the action of contracting fibrous tissue, into a U-shape (*Fig* 271); some of the loops hook over each other. Hence the ever-differing irregular arrangements of the nerve fibres within the bulb—the internal plexiform neuroma, as Professor Marinesco of Bucharest termed it.*

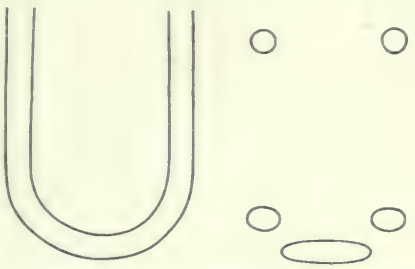


Fig. 271.—To illustrate how a nerve fibre growing alongside a bundle of scar tissue can be made to turn completely round and grow backward, forming a U. Also its appearance on section at the different levels.

The ascending neuritis—as evidenced by the increased amount of connective tissue between the nerve bundles, and its added vascularity—travels up between the fibres in the central part of the nerve trunk. In the nerve end there is little or no separation of the nerve fibres near the periphery. The bundles of central fibres become more tortuous and further separated from each other as they approach the bulb (*Fig.* 272). On reaching the bulb, they undergo more twisting, forming a well-marked 'zone of twisting.' Beyond this the nerve bundles come closer together, interlacing with the centrally-bent peripheral fibres to form a dense tissue in the central parts of the bulb,

* *Proc. Roy. Soc. Med.*, 1918, xi, p. 5.

the 'zone of lacing.' This tissue gives the bulb its hardness, and the small amount of closely-packed connective tissue between the bundles of nerve filaments allows of only a very little swelling before causing pressure on nerves and a painful sensation. This, then, is a situation where very little inflammation may cause much pain. The dense network produced by the interlacing and tortuosity of the central and peripheral nerve fibres becomes looser as the apex of the bulb is approached. Finally, the apex is penetrated by the terminal perforating fibres.

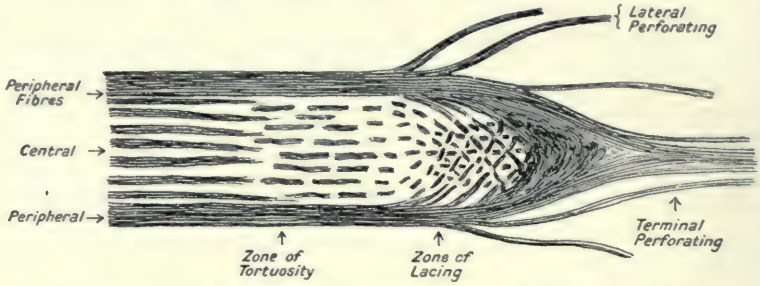


FIG. 272.—Scheme of nerve conformation in bulb.

On making a section of the bulb, the network of nerves, the 'zone of lacing,' protrudes in an irregularly convex form, the pressure on one side being relieved by the section.

The part of the end bulb formed largely from the inner and middle coats, the endoneurium and the perineurium—the core of the bulb—is not always central and symmetrical, and gives different shapes to the bulbs by its variations. Over this central mass and in continuity with it is the epineural cap of fibrous tissue. It is well to visualize this cap of connective tissue, which has begun to contract before the regeneration nerve fibres have

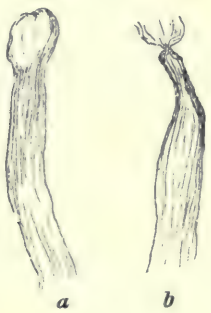


FIG. 273.—*a*, Nerve bulb; *b*, Nerve pencil; drawn from actual specimens removed by Major Chapple. The nerve which formed the bulb was cut across. The nerve which formed the pencil was amputated by the sleeve method.

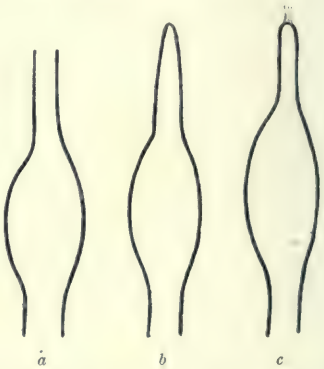


FIG. 274.—*a*, Nerve bulb, formed mostly from the endoneurium and perineurium after nerve division by crushing. *b*, The above with a nerve pencil, formed by the amputation of the nerve with a sleeve of epineurium distal to the crushing. *c*, The regeneration from the point of the pencil end.

grown into it. Unfortunately a little contraction on an inflamed nerve fibre causes much pain. In the nerve pencils, as contrasted with the bulbs, the epineurium is preserved as a sleeve, and does not participate directly in the formation of the nerve endings.

A *nerve bulb* is formed by dividing the epineurium, perineurium, and endoneurium at the same level. (*Figs.* 273 *a*, 274 *a*.)

A *nerve pencil* is formed by dividing the perineurium and endoneurium at one level and the epineurium lower down, so as to cover the stump with a sleeve of epineurium. (*Figs.* 273 *b*, 274 *b*.)

A *nerve spindle* is formed by partially dividing both the endoneurium and perineurium and leaving the epineurium intact. (*Fig.* 274 *c.*)

The several forms of bulb are fashioned by the varying parts which the different nerve coats take in their formation. When the fibrous core to the cap just referred to is in the centre of the bulb, the peripheral nerve fibres are distributed symmetrically around it; but if it is eccentric, the fibres situated on the periphery of the nerve trunk pass it by asymmetrically, more on one side than on the other, and being curved round its surface, as directed by the fibrous tissue of the cap, some interlace and others escape at the apex of the bulb. Thus, the end bulb ceases to be an end of the nerve. Regenerating fibres pass it by; some escape by the side of the bulb, and some from the apex. The more eccentric the core, the more peripheral fibres will be on one side or the other.

Practically, the end bulb is not an end of the nerve fibres: these can grow into any adhesion or along any scaffolding of connective tissue. The adhesion of a nerve bulb to a muscle is a very frequent event in painful conditions, and the scar tissue of the adhesion offers a scaffolding for the nerve fibre to grow along and infiltrate the muscle, every contraction of which must jar the bulb. This has been demonstrated, and in addition Professor Marinesco has shown new nerve fibres from the median nerve infiltrating the tendon fibres of the flexor sublimis digitorum. In these cases the adhesions are almost always lateral to the bulb, being particularly frequent on that side of the bulb where there are most peripheral fibres. Of all the nerves of the body, adhesions to muscles are most frequently found on the stump of the sciatic.

It is chiefly the fibres which escape from the sides of the bulb that infiltrate the surrounding structures through the adhesions to the latter. From the apex of the bulb fibres strain out, and, like a river, seem to follow the line of least resistance. Usually this is by the old course of the nerve, or else along the vessels. Thus, the internal saphenous nerve from Hunter's canal on the front of the thigh may communicate with a regenerating sciatic behind via the course of the vessels.

Regeneration Neuromata.—Should the flowing growth of the regenerating fibres meet an obstruction, they bank up, as a stream forms a lake, so causing a tumour of new growth, a regeneration neuroma. The regeneration neuromata are far more often found on small nerves of devious course than on large nerves which run a plain easy path. On small nerves they are multiple and coursal, along the nerve's course, whilst on large nerves they are simple and terminal. These regeneration neuromata have been found most often—and multiple, three or four—on the internal saphenous nerve; less often and less in numbers on the small sciatic nerve. Never have they been found multiple in the arm, though there is no apparent reason why they should not so exist; perhaps the true reason is that the arm in general produces simple and straightforward problems and conditions as compared with the leg. Regeneration neuromata grow mainly in the leg; they may be multiple; as single tumours they form the terminations of all large nerve trunks formed by regeneration, and consist of a large and varying amount of fibrous tissue and a small and varying amount of nervous tissue.

Nerve-bulb Pain.—What makes the nerve ends painful? There are several theories. The first has been most recently and loudly advocated by Captain Sydney Cone in a long and learned paper.* After much labour and research he has found and elaborated a specific stain for neurokeratin. From a study of the results he has concluded that "three-fourths of each (painful bulb) consists of young nerve fibres," and that "they cause pain apparently by their excessive proliferation against resistance" of scar tissue. One can follow this theory quite well, and easily understand that, within reason, the older the bulb the more numerous the nerves within it. But as a clinical explanation the theory fails, because after section every nerve end is tender for four to six weeks. In normal cases the tenderness disappears just at the time when the intrabulbous nerve pressure

* *British Journal of Surgery*, 1918, v, No. 20, p. 524.

from the growth of young nerves should be coming into operation. In such a common and normal case the theory of neural-growth causation of nerve-end pain fails.

Perhaps the most popular theory of nerve-bulb pain was that it was due to constriction and compression from the contraction of the scar tissue in and around the bulb. Many examples of this condition are to be found in studying the structure of nerve bulbs, both in those which clinically are painful and in those which are painless. The following may be cited :—

1. When a microscopic section is made of a nerve which has not been hardened as it lay stretched out, the fibres are seen to be waved. In the same section there are often both waved and straight fibres, showing that some are held out very taut—most probably by the fibrous tissue between the nerve bundles—whilst others are not so held. There is evidence of tight hold, if not of strangulation.

2. The interior of a nerve bulb is filled with a network of nerve fibres, loops of which knot with other loops, the knots so formed being more or less tightly drawn. A section of a painful neuroma showed this, and also the tortuosity of the fibres in the bulb, its

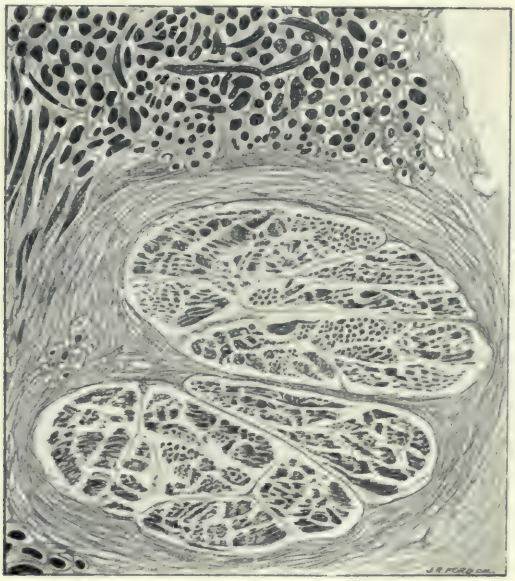


FIG. 275.—Showing nerve fibres crushed by the contraction of the surrounding fibrous tissue. Nerve fibres without a capsule, and uncrushed, are shown at the upper part of the section. (× 30.)

great vascularity, and the large amount of œdematous fibrous tissue within it. The nerve bundles were very twisted.

3. The fibrous capsule of the bulb is not often contracted so as to be observable with the naked eye, like that of a hobnailed liver. Occasionally a bulb is seen to be wrinkled, with fibrous downgrowths into it. More frequently the contractions can only be seen with a microscope.

4. In another section there was a strangulated island of nerve tissue, the strangulation being suggested by the irregularity of the neural waves in the pinched 'island.' They were like those on boiling fluids.

5. A section of a sciatic nerve showed a very remarkable state of affairs. Growing down from the capsule of the bulb was a band of fibrous tissue, which divided, embracing many nerves in a kind of alveolar arrangement. By contraction of the walls the contained nerves were crushed. In the drawing (*Fig.* 275), crushed and uncrushed fibres may be compared.

6. A section of a strangulated nerve showed œdema of the interfascicular connective tissue, starting from the point at which the fibres were constricted. Œdema was present in all parts distal to where the lymphatic flow was impeded.

7. A section from another case also showed strangulation and twisting of an œdematous nerve bundle.

8. Another section was interesting as demonstrating a slight strangulation of two nerve bundles by a bridge of scar tissue, which only pressed sufficiently to damp off the size of the waving as the bundles passed under it.

9. In another section the nerve bulb showed a strangulated and twisted nerve bundle, with increased amount and vascularity of the connective tissue.

10. A section showed a strangulated nerve island, with increased size and irregularity of the waving. There was also a band over a nerve bundle, which was constricted at that point, the nerve-waving being damped off.

11. Another section showed very clearly a strangulated and twisted nerve bundle, with increased vascularity and quantity of interfascicular connective tissue.

12. Another section showed the presence of a large collar of scar tissue which by it contraction had bitten deeply into a nerve bundle, causing its severe strangulation.

13. In another section there was strangulation of a severely constricted nerve bundle.

Doubtless these two factors, the raising of the intrabulbar pressure by neural growth and the contraction of the fibrous tissue, have some significance. They can be found, however, when there is no complaint of pain, and consequently cannot be regarded as giving a pathological explanation of this clinical symptom. Professor Marinesco and I have shown* that the true explanation is to be found in the raised intrabulbar pressure and the irritation of an infective inflammation which is the characteristic of painful stumps, and that this is favoured by the presence of foreign bodies, reaching the nerve bulbs by direct extension if the nerve has not been cut short, or indirectly by the lymph stream if it has. If these foci of inflammation should be in the 'zone of lacing' of a nerve bulb, pain is quickly and easily caused, as there is little room between the nerve bundles for swelling. A swollen nerve is more susceptible to twisting, pressure, and strangulation, and more painful therefrom. Doubtless, therefore, increased intrabulbar pressure accounts in some degree for the pain of nerve endings; but the pressure and irritation of infective inflammation is the prime factor which produces the pain. As the presence and extent of this factor has been frequently demonstrated by me elsewhere,* no more need be said here. In this report I wish to consider the various shapes of nerve bulbs, their methods of production, and the zones of contraction around them, as these have not been detailed previously.

Nerve bulbs take four shapes; three of these are fairly well known, but one has been noted only recently, and is as yet imperfectly recognized. They are (1) The nerve bulb; (2) The nerve pencil; (3) The nerve spindle; and (4) The nerve drop.

1. The first of these is the best known by far, and is produced by merely cutting across the nerve transversely or obliquely. Roughly, it is made up by the coats of the nerve as follows: Near the regenerating fibres is a mass of scar tissue resulting from the repair of the endoneurium; outside this is a cap of perineurium; and most external is a cap of epineurium. Why has the trouble been taken to enumerate these facts? The answer is that only in the bulb and close to it is a regenerating nerve fibre in danger of compression. Once let the fibre penetrate beyond the cap of scar tissue furnished by the nerve coats, and it will have grown into a region where the scar tissue has largely ceased to contract and now merely acts as scaffolding along which the regenerating nerves grow. Only near the bulb does the regenerating nerve fibre run the risk of being compressed. Once beyond,

* In a lecture at the Royal Society of Medicine in April, 1918, and later, I have demonstrated to the Surgical, Neurological, and Electro-therapeutic Sections of the Royal Society of Medicine in May at the Welsh Metropolitan War Hospital, Cardiff, in April: and at St. Thomas's Hospital in May.—*Proc. Roy. Soc. Med.*, 1918, June; *Brit. Med. Jour.*, 1918, June.

it is safe, except for accidents, such as where it is strangulated and adherent to bone, as in a Syme's amputation.

2. The nerve pencil is a very definite structure which is produced by amputating the nerve so as to cover the stump with a sleeve of epineurium. This method only fails in its technique. Epineural flaps are sometimes 'holey,' and indeed inefficacious, in their fashioning. They are condemned by Captain G. M. Huggins in his excellent little book on amputation stumps.* Captain Huggins has had an unrivalled experience of amputation stumps at Brighton, added to an extended surgical experience at St. Thomas's Hospital, and later in South Africa. His opinion is therefore valuable. But undoubtedly the zone of certain compression around the tip of the nerve pencil is smaller than that around the nerve bulb (*Fig.* 276). A nerve pencil can be made by crushing the nerve and transfixing and ligating the crushed part with fine catgut. This method I have often used, and it is more certain than any epineural sleeve; but experiments often reveal that a number of the fibres were not divided by the crushing, the filaments only being compressed. The epineurium (outer coat) was rarely divided except by Kocher's crushing forceps. The best instrument I found was the smooth appendix clamp made for me in 1903 by Messrs. Allen & Hanburys.

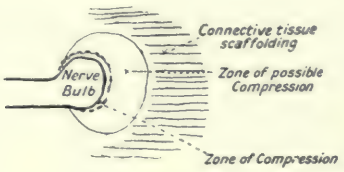


FIG. 276.—Diagram to illustrate the zones of nerve-fibre compression by the cicatrization of the scars next to the nerve end. The innermost zone, mostly derived from the endoneurium, is that of certain compression. The middle zone, mostly derived from the perineurium, is that of possible compression. The outer zone, mostly derived from the epineurium, contains scar tissue which has ceased to contract, and its fibres act as scaffolding to the growing nerve shoots.

3. The nerve spindle is produced by crushing the nerve, the object being to divide the nerve fibres and not the connective-tissue coats. This has been accompanied by varying success. The vasa nervorum certainly did not bleed. But the method was discarded because the crushing caused a certain amount of epineuritis around the nerve, with subsequent pain, adhesions, and a generally unsatisfactory condition.

4. One of the most successful methods of nerve amputation for curing pain is by nerve anastomosis, but the method is too laborious for ordinary use. Its results are excellent, and seem to depend on the thoroughness with which the steps of the operation are done. It has been modified and made more generally useful by the L-operation. This method gives rise to a nerve drop; but it is too recent for its results to be really known yet. Its bulb is certainly very like the ordinary end bulb, but longer.

The usual method in my practice is that of the 'swing door.' The nerve is gently drawn down, divided by two cuts (one from either side), and then allowed to retract, the backward movement closing the flaps like swing doors. It forms a bulb like the ordinary bulb, but the nerve is shortened and its end closed cleanly and without stitches or manipulation.

Lastly, there is the nerve triangle to be mentioned. It is found particularly in the musculospiral and posterior tibial nerves, and is produced by the nerve becoming adherent to bone, its end being unable to expand to form a bulb. The result is a very flattened nerve end, often of triangular shape, as when a nerve becomes attached to a bony spur.

The zones of compression about a nerve end are clinically not much affected by the shape and fashion of the bulb. The cause of the pain is not compression of the nerve trunk: that only accentuates the pain already created by the foci of inflammation within the bulb, and is in no obvious way affected by the shape of the nerve end.

* Frowde, Hodder & Stoughton.

INJURIES OF THE PERIPHERAL NERVES FROM THE SURGICAL STANDPOINT.

By Major H. S. SOUTTAR, R.A.M.C., and Captain E. W. TWINING, R.A.M.C.

Injuries of the peripheral nerves present one of the most difficult problems which have arisen in the surgery of the war. The curious inquiry of a few specialists has suddenly become a question of urgent importance, the answer to which it is hard to find. Not only must the general surgeon undertake operations with the technique of which he is not familiar: the surgeon who has had previous experience of nerve injuries in civil life finds himself confronted by problems which tax his ingenuity to the utmost, many of which are still unsolved. It has therefore appeared to us that the careful consideration of cases which have come under our notice might be of some value at the present time. We propose to give an account of these cases, of the observations which we have made, and of the deductions which we consider may be drawn from them. By presenting the whole of our material in an abbreviated form, we hope to make it possible for any who may care to study it to decide for themselves whether or not our deductions are justified, and to give to each of these its proper value. We shall entirely avoid speculation, and shall limit ourselves stringently to what we have ourselves observed.

We are confronted at the outset by the difficulty of keeping patients under observation for a sufficient time. Some cases, however, we have been able to follow through to their recovery, and by adding a brief Summary to most of the case histories in *Appendix B*, we have been able to place in their true perspective our observations on those cases whose record is less complete. This seemed to us better than to discard cases of great interest—many of them those from which we have learnt the most.

This paper is founded on the series of cases of nerve injury which have passed through this hospital in the last two years. We have excluded cases of a trivial or transient nature, and those which were transferred to other hospitals before adequate observation could be made. The cases were under the care of the various medical officers of the hospital, to whom we would record our thanks, and to whose skill the recovery of many of the patients was due. For notes on some of the earlier cases we are indebted to Colonel Miller, A.M.S., of whose admirable records we have made full use.

Our observations were made on 128 cases, which may be grouped as follows:—

Nerve	Operation	No Operation	Total
Ulnar	18	10	28
Median	7	6	13
Median and ulnar	8	2	10
Musculospiral	8	13	21
Posterior interosseous ..	3	3	6
Musculocutaneous	1	—	1
Brachial plexus	9	2	11
Internal popliteal ..	2	2	4
External ,, ...	7	9	16
Internal & external popliteal	7	5	12
Lumbar plexus	—	1	1
Facial	—	6	6
Total cases ..	70	59	129

METHOD OF EXAMINATION.

In examining our cases a definite routine has been followed, and the examination itself has been reduced to as simple a form as possible. A complete investigation of every case would have furnished work for an army of neurologists, without practical results of commensurate value. By very simple methods it is possible to discover

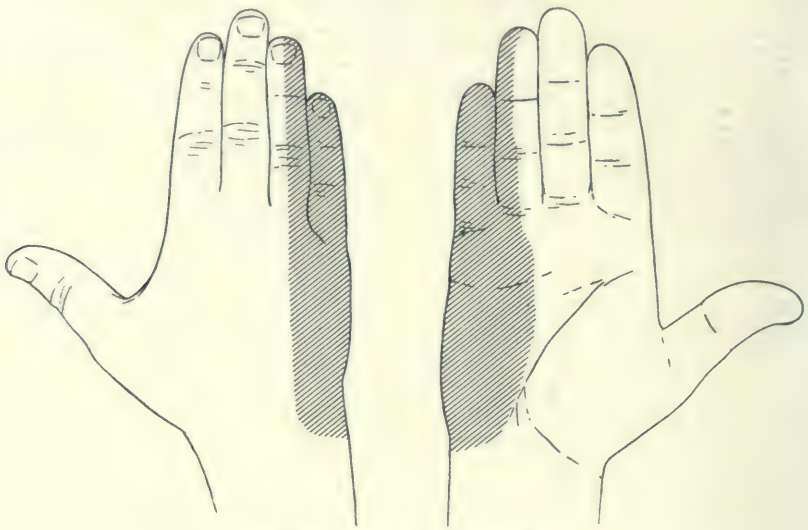


FIG. 277.—Ulnar area of anæsthesia.

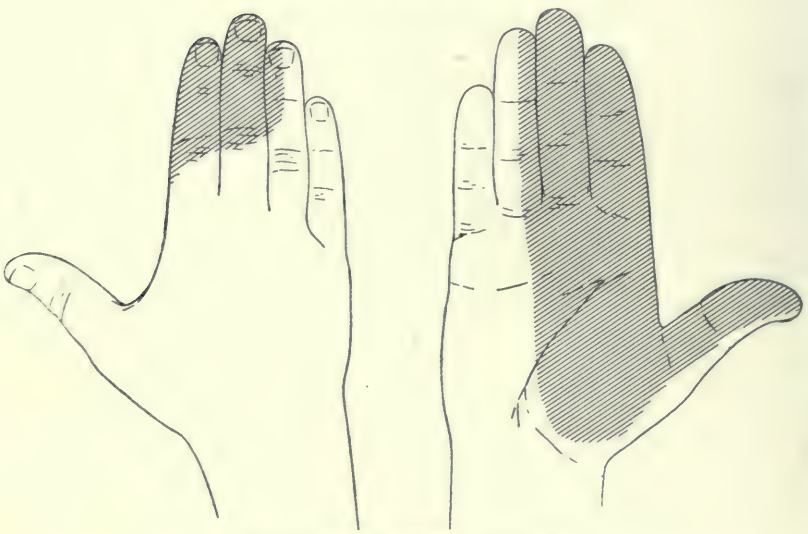


FIG. 278.—Median anæsthesia, full area.

the site of injury, and to estimate its degree. By similar examinations at intervals of a few weeks we can follow the course of a case and form some idea as to its prognosis. By the time wounds are sufficiently sound to allow of operative procedures, we shall be in a position to decide on the advisability of the latter, and in

most cases we shall be able to state whether neurolysis or actual resection is required. We would lay stress on the great value of continuous records even of the simplest nature, as against a single investigation even of the most elaborate completeness.

Sensory.—Cutaneous sensation is tested with a soft camel-hair brush and a pin. The former, if lightly used, furnishes a convenient and rapid means of mapping out epicritic sensation, but the charts of protopathic loss obtained by pin-prick are more reliable, and, with the rather insensitive skin of the soldier, are more readily obtained. In general the difference between the areas is negligible, the protopathic loss being the smaller except in very high lesions of the nerves. It is essential that no confusion should be caused by deep sensation, which a brush may arouse by moving the hairs whose roots are supplied from this source, and a pin through pressure. Deep sense is carried up by tendons and motor branches along routes entirely different from those which serve other cutaneous impulses; it often remains intact in complete lesions of the main trunks of supply, a fact which is responsible for many of the cases of 'early recovery' of which one reads. The areas of sensory loss corresponding to the principal nerves are shown in the charts (*Figs.* 277–280). It must, however, be noted that these are by no means constant, and that they do not always correspond with the areas described in anatomical text-books. We are, in fact, dealing with function, and not with the gross distribution of fibres. Thus, the large area of anatomical radial supply is in striking contrast to the minute area of sensory loss which is found in complete lesions of this nerve. The fact is that a large part of the skin has a multiple supply, and it is only in that part which is exclusively supplied by the affected nerve that sensory loss is seen. In irritative lesions of nerves, on the other hand, the whole anatomical area of supply is affected, and in such cases this area can be mapped out as a region of extreme sensitivity.



FIG. 279.—Musculo-spiral anæsthesia, usual area. Dotted line shows complete area.



FIG. 280.—Sciatic areas of anæsthesia.

Trophic.—Trophic changes are rarely marked except in the case of partial and irritative lesions. The skin may be dry and covered with a branny desquamation, or glossy and glistening with minute beads of sweat, or it may be sodden and offensive and covered with a thick layer of cutaneous débris. These changes appear to be largely due to want of use of the limb, for when the nerve has been freed or sutured, and the limb efficiently treated by massage and baths, they rapidly disappear, long before any recovery of nerve fibres is possible. In our experience trophic changes in limbs under full treatment are insignificant.

Motor.—The motor results of a nerve lesion are by no means as easy to demonstrate as might at first appear. An accurate knowledge of the nerve-supply of the

various muscles, and of the exact movements which each produces, is essential. With each nerve there are certain critical movements for which we must look, and there are certain errors which we must avoid.

The musculospiral produces extension of the wrist and of the proximal joints of the fingers. Extension of the two interphalangeal joints of the fingers is produced by the lumbricals and interossei (median and ulnar), and abduction of the thumb by the abductor pollicis brevis (median), which in some cases sends a slip to the dorsal expansion on the thumb, and can thus produce extension of the terminal phalanx.

The characteristic movements produced by the median nerve are flexion of the index and of the thumb, and opposition of the thumb. In the last movement rotation of the metacarpal is the essential feature, the thumb nail turning to face the observer looking at the palm. In adduction of the thumb produced by the adductor pollicis (ulnar), this rotation does not occur.

Only the ulnar can produce complete flexion of the little finger and ulnar flexion of the wrist. But the chief feature of an ulnar lesion is the wasting of the small muscles of the hand, specially noticeable in the first interosseous space. The little and ring fingers assume a slightly clawed position, but the complete claw-hand is only seen in combined lesions of the median and ulnar, where all the lumbricals are paralysed.

In complete lesions of the median and ulnar, flexion of the wrist can still be performed, and is at first sight a very perplexing phenomenon. It is carried out by the short extensors of the thumb, which pass slightly to the front of the wrist-joint.

Lesions of the brachial plexus may give rise to paralyses of great complexity, but they can often be easily resolved if it is remembered that section of the fifth cervical root produces paralysis of the deltoid, biceps, brachialis anticus, and supinator longus, whilst section of the first dorsal root produces paralysis of all the small muscles of the hand, which becomes completely clawed.

In the leg, movements are simpler, and loss thereof is more easily referred to its source. The external popliteal elevates and everts the foot, the internal popliteal depresses it. But it should be noted that quite powerful flexion of the ankle can be produced by the peronei, accompanied, however, by very marked eversion. Even in high lesions of the sciatic, paralysis of the hamstrings is rare, and in none of our series has it been complete. The lumbar plexus is so placed that injuries to it are usually fatal; only one instance occurs in our series.

Electrical.—The tests which we use for diagnosis are of the simplest nature. Two small spherical pads are used, connected with a variable galvanic or faradic supply with a metronome interrupter in the circuit. Ten days after a complete nerve lesion the reaction of degeneration can be obtained, with the slow, undulatory contraction to galvanism and the absence of any reaction to faradism. But in our experience paralysed muscles vary greatly in the rapidity of their contraction, some reacting quite briskly when the nerve is known to be entirely severed. A more constant phenomenon is the slow relaxation which occurs, so slow that a quick metronome interrupter may have had time to send a fresh stimulus before relaxation from the first contraction is complete. The electrical reactions are of importance in that they enable us to eliminate the possibility of a functional paralysis, which may perhaps have followed on a real but trivial injury to a nerve. In such a case the muscles will always respond readily to a faradic current.

CARE OF THE LIMB.

The lesion diagnosed, the next thing is to make arrangements for the care of the limb. It is essential to remember that upon the amount of trouble and skill expended on the limb before operation the ultimate result will largely depend. Muscles must be kept relaxed and in good condition, tendons must not be allowed to become adherent, nor joints to become stiff. It is not sufficiently realized that it is quite

possible to keep a paralyzed limb in such perfect condition that only an expert can detect from its appearance that any abnormality is present. The so-called trophic changes are largely the results of neglect, not of any inevitable pathology.

Massage.—This should be started at the earliest possible moment, and splints should be so arranged that as much as possible of the limb can be reached. A gentle exercise for the muscles is thus obtained, the lymphatic circulation is stimulated, and the skin is kept in a healthy state. Very special attention should be paid to the fingers and to the preservation of their complete mobility, particularly at the metacarpo-phalangeal joints. A few weeks' neglect may result in a stiffness of the hand from which recovery may be impossible.

Mechanical Treatment.—As repair proceeds, it is possible to adopt more vigorous methods, and many ingenious appliances have been devised for persuading the patient to use his limb, for it must always be remembered that this is the ultimate goal. In those of the Zander type a pendulum or flywheel is always included, the inertia of which tends to carry each movement a little further. Others provide graduated resistance to various movements, requiring more volitional effort on the part of the individual. We have a large department equipped with both types, and the men pass from one machine to another, obtaining variety of exercise and of interest.

Whirlpool Baths.—The whirlpool bath is a form of treatment which we owe to the war, and we are becoming every day more convinced of its value. As our equipment presents some novel features, it may be worth while to describe it in some little detail. It is specially well suited to the requirements of a hutted hospital, where the water-supply is limited, and where a large supply of hot water under pressure is unobtainable.

Our baths are so arranged that heated water from a tank is driven by a centrifugal pump through the baths, and returns to the tank by gravity. The temperature of the water is maintained by a small gas-heater through a separate circulation. This system is extremely economical, both in construction and in use, for only about 500 gallons of water are required to operate our twenty baths, and the loss of heat is so small that only a bye-pass is used for the gas after the water has once been heated. As 3000 gallons of water per hour are driven through the baths, the economy of water and of heat will be obvious. The water is changed once a day, and this appears to be quite sufficient. No inconvenience has arisen from the repeated use of the same water. One great advantage of the system is that it is self-contained, and requires only a small water-supply, a small source of heat, and a small source of energy. It can be controlled by an orderly of average intelligence, and it is almost impossible to put it out of order.

The cost of our original installation of eleven baths was about £200, and the cost of maintaining these was about 1s. per hour. In our present installation we have introduced an air-compressor, a somewhat expensive addition, though it adds considerably to the possibilities of treatment. The total cost of the apparatus, with twenty baths, as it at present stands would be about £500. It is our routine practice to give twenty minutes in a bath, followed immediately by ten minutes' massage. The chief effects of the bath are a great increase in vascularity and a remarkable softening of the tissues, with the result that massage is greatly facilitated and much time and labour are saved. The freedom of movement of joints and muscles which follows immersion in a bath is very striking. In a few days the skin, from being glazed and atrophic, becomes soft and thick, the muscles become supple and elastic, and the mobility of the joints is increased. Even in the case of extensive nerve lesions the appearance of the limb becomes almost normal, and the familiar trophic changes are almost entirely absent.

We regard the whirlpool bath as the most powerful curative physical method at present at our disposal. It facilitates other methods, softening the limb for massage, and increasing its conductivity for electricity ; it reduces pain ; and it produces in the patient a feeling of well-being in the limb which stimulates him to those voluntary exertions without which no complete recovery can be obtained. A very important feature of the

treatment is the great economy in massage effected. The duration of massage has been reduced from 30 to 10 minutes, the actual process is easier and less laborious, while the results are in every way superior to those which we could previously obtain.

Electrical Treatment.—There has been a considerable development in electrical methods of treatment to meet the requirements of war surgery. Many ingenious appliances have been evolved, of which we make full use, but it is only possible to mention briefly a few of these in the present paper. In the treatment of muscles whose nerve-supply is completely severed, the interrupted galvanic current still holds the first place, and will form the basis of any routine. It may be applied in several ways. We usually place a large pad connected with the positive pole around the proximal part of the limb, and a small pad is moved from point to point over the distal portions of the muscles till satisfactory contractions of each are obtained. Interruptions are produced by a metronome, and a rheostat controls the potential. A general stimulation of the muscles may be obtained without the use of any interrupter, the variations of current produced by sliding the small pad from point to point being sufficient to evoke contractions. It is important in any case that the current should pass longitudinally along the muscle fibres, and in the case of a paralyzed muscle the best contractions will usually be obtained by placing the small pad in the region of the tendon of insertion. Care should be taken to avoid fatigue, and when a muscle shows signs of flagging, another should be selected for stimulation.

In some cases, however, this method is too painful, especially where the lesion of the nerve is incomplete. In such cases we have obtained excellent results from the slow galvanic oscillation given by a Wilson modulator. The action of this machine depends upon the remarkable circumstance that a paralyzed muscle may be made to respond to a galvanic oscillation too slow to stimulate a normal muscle. It is thus possible to obtain dorsiflexion of the wrist in a case of complete musculospiral paralysis without corresponding contraction of the flexor muscles.

As the nerve recovers and the faradic response returns, it is important that full use should be made of the more complete and lasting contraction which this form of stimulus evokes. It may be applied through pads similar to those just mentioned, or one of these may be replaced by a small roller. In other cases the limb is immersed in a bath, through the length of which a faradic or sinusoidal current flows, varied by some form of interrupter, sudden or gradual.

The high degree of skill required for effective electrical treatment is not always appreciated, and we would lay stress on the importance of thorough training in those who carry it out. The actual operator must have some knowledge of the action of the various currents used, of the anatomy of the muscles, and of the movements produced by their contraction. And her work must be supervised by an expert fully trained in all these matters. The unskilled use of a coil or a battery cannot be too strongly deprecated. It can only cause disappointment, and may produce serious damage.

Splints.—In the intervals between treatment, the limb must be kept warm and its insensitive portions protected from injury. Light splints must be carefully applied in such a manner that, whilst they keep paralyzed muscles intact and prevent development of contractures, they interfere as little as possible with the use of the limb. We consider however, that the statements which have been made as to the dangers of stretching a paralyzed muscle have been greatly exaggerated. It is certainly essential that the muscles should be kept relaxed during the greater part of the day and night. When, however, the splints are removed by the masseuse, it is our custom to flex and extend the joints over their full range of movement, and we have never seen ill results follow. We should like to enter a word of warning against the grotesque positions into which limbs are sometimes forced on the plea of obtaining more complete muscular relaxation. The limb should be held in an easy and natural position and one which will ultimately be of use to the patient. In the case, for example, of a musculospiral paralysis, far better results will be obtained by using a small cock-up splint in the palm, and allowing the fingers to flex, than by maintaining these in an extended position.

INDICATIONS FOR OPERATION.

The indications for operation do not depend on the results of any one examination, but upon the close consideration of the progress of the case. It is therefore our custom to see every case at the earliest opportunity, and to make exhaustive notes of the condition found, although from the nature of the wounds it may be obvious that an operation cannot be contemplated for several months. The case is seen every month, and any changes are noted on charts. The question of operation is not considered until the wounds have been soundly healed for two months, when such a mass of information has been collected that a decision is no longer difficult. If the nerve shows signs of active recovery, operation will be deferred. Such signs are—a reduction in the area of anæsthesia, or a quickening in the galvanic response of the muscles, especially a shortening of their period of relaxation. If, however, there is little or no recovery, it is far better to explore and to discover the actual condition of the nerve than to waste further time in waiting. But before undertaking an exploration, the surgeon should have a very clear idea as to whether resection of the nerve will be required, or whether freeing it from scar tissue will suffice. The most difficult cases of all to deal with are those in which a portion only of the nerve is totally destroyed. In these the most careful record must be made of the voluntary movements present, and the operation must be performed under control of repeated electrical stimulation of the nerve, as only in this way is it possible to discover and preserve the uninjured fibres. We are strongly in favour of exploring all doubtful cases: in looking through our records we much regret that we did not always take this course. It is one thing to suggest exploration to a patient soon after an injury, and quite another to advise it after six months of abortive treatment.

CONDITIONS FOUND.

As regards the conditions found at operation, it is possible to lay down one general premiss—the injury to the nerve is always much more considerable than might have been expected from the clinical signs. The fact is that the nerves contain a great excess of fibres above those actually required, and a third of the cross-section must in general be destroyed before any permanent disability will result. The portion of the nerve which is injured is very obvious, its natural soft and striated structure being replaced by a dense knot of fibrous tissue. In some cases this will occupy the whole of the nerve; in others only a portion of its structure is destroyed, the remaining fibres passing down as a more or less uninjured band. In such cases we test the electrical conductivity of the nerve by bipolar stimulation with the faradic current above and below the point of injury. Owing to a partial block at the site of injury stimulation above will almost always require a more powerful current than stimulation below, and the strength of the current required gives some indication of the condition of the fibres concerned.

In other cases so much of the nerve will have been destroyed that no continuity exists, there being a gap of several inches between the last discoverable portions of the nerve, which, in such a case, will usually terminate in end-bulbs. Sometimes one end of the nerve will be found embedded in bone by the projectile which caused the injury. In one of our cases this last condition gave rise to a sciatic causalgia so severe that the nerve had to be divided in the open wound.

In other cases the nerve can be shelled out from dense fibrous tissue, in which it is apparently being strangled. In some of these the nerve, when freed, may present no abnormality in appearance or consistence, beyond a slight constriction, the injury apparently being entirely limited to the perineural structures. In general, however, there will be some degree of fibrosis in the nerve itself. The slighter degrees of injury are those most frequently associated with pain, which would seem to be due to a definite neuritis rather than to the actual trauma, for the nerve is often found to be swollen and indurated for some distance above the point of injury.

In testing these nerves electrically, we use two small metallic points, placed at a

distance of about four millimetres, and connected with a weak faradic source. We are in the habit of gauging the strength of the current by applying these electrodes to the neighbouring muscle, and we would call attention to the fact that a muscle whose nerve is already divided responds to such stimulation with the slow contraction typical of the reaction of degeneration. It is therefore an error to state without qualification that a paralyzed muscle cannot respond to faradic stimulation.

INDICATIONS FOR RESECTION.

If the continuity of a nerve is found to be completely destroyed, either absolutely or by a fibrous knot, it is of course obvious that recovery can only be obtained by resection of fibrous portions and direct suture of the uninjured trunks. If any fibres of the nerve remain which have escaped injury and can be dissected from the injured part, these should be most carefully preserved, provided that this can be done without prejudice to the suture of the remaining portion. We are convinced, however, that it is a mistake to spend too much time in saving a few fibres of doubtful utility. Clean resection of a whole nerve can be carried out with much greater precision than is possible when a portion of the nerve is left.

The most difficult cases in which to reach a decision are those which are associated with extreme pain in the nerve distribution. The pain can certainly be abolished by alcoholic injections, but where a part of the nerve is destroyed and resection is essential, alcoholic injections may seriously prejudice the ultimate result. In partial lesions associated with severe pain, where a considerable portion of the nerve is definitely fibrosed, we prefer complete resection of the nerve with end-to-end suture.

There is no detail in the surgery of nerve injuries which calls for more experience or where a careful judgement is more essential. Our experience so far favours complete resection with end-to-end suture in all cases where there is not some very obvious reason for taking another course.

OPERATIVE TECHNIQUE.

To a surgeon who proposes to operate upon the peripheral nerves, accurate knowledge of their anatomy is essential, and it is difficult to see how the intimate knowledge required can be obtained except by spending some time as a demonstrator in the dissecting room.

The difficulties of identifying the two ends of a divided nerve, in a limb where all the ordinary landmarks have been destroyed, can scarcely be exaggerated. One has to rely for their discovery on minute details, or else to make dissections which are mutilating in their extent. Unfortunately this is far from being universally recognized, and it is no uncommon thing for a man whose anatomical studies ended with his student days to attempt a complete dissection of a brachial plexus from a fibrous scar, a feat of which any anatomist might well be proud. It is surely most unfair to a patient that any surgeon should undertake such a critical operation as the suture of a nerve without equipping himself by every means in his power to meet the difficulties he may encounter.

Exposure.—An incision is made in the course of the affected nerve of such dimensions that the peripheral and distal portions of the nerve can be readily found in approximately normal tissue. This is far better than to attempt first to discover the nerve in the actual scar tissue, where it may quite well have ceased to exist. The ends exposed, these are carefully followed into the scar, and the whole nerve or its divided ends are then isolated.

In exposing the nerve, as little damage to surrounding structures should be done as is practicable ; but it must always be remembered that the recovery of the nerve is the aim of the operation, and that very heavy sacrifices may be desirable if this object is obtained. The complete division of a large muscle such as the gluteus maximus, or the resection of several inches of the humerus, would in general be bad surgery ; in the surgery of nerves such proceedings may be essential. It is impossible to reach the

sciatic nerve in the neighbourhood of the pelvis without dividing the gluteus maximus; and although it may be sometimes possible to turn down a portion of the muscle, or to divide it in the direction of its fibres, cases will occur where the only satisfactory course is to divide it transversely.

Testing Conduction.—The nerve satisfactorily exposed, it is necessary to decide, if it is not already divided, upon the advisability of a resection. To a large extent the decision will have already been made, and will depend upon the previous course of the case. In all cases, however, we test the conductivity of a continuous nerve to faradism, both above and below the point of injury. If conduction through the injured portion is not seriously impaired, and if the degree of fibrosis of that portion is not extreme, it is better to be content with having freed the nerve, dissected it free from all fibrous tissue, and formed for it a protective bed of fat or muscle. If conductivity is poor, and fibrosis is extreme, resection of the damaged part is in general to be preferred

Resection.—A question of great importance now arises—the extent of resection which is possible, or advisable, if end-to-end suture is to be performed. We can here lay down two propositions which cannot be disputed. First, that unless so much of the nerve is resected that healthy fibres are exposed, the operation will be nugatory. Second, that the results of end-to-end suture far surpass those of any other method at present known. We therefore decide first upon the length of nerve which will probably have to be removed before healthy fibres are reached; and then try to devise some means for bringing the nerve ends together. If the nerve be widely freed above and below, it is remarkable how much can be removed without producing undue tension after suture, provided the position of the limb is carefully arranged. Thus, we have resected nearly three inches of the ulnar nerve, and obtained a direct suture by flexing the wrist, extending the elbow, and adducting the arm close to the side. We prefer this method in most cases to the more drastic one of dislocation in front of the condyle. In the latter the branch to the flexor carpi ulnaris is very liable to injury. For the median, flexion of the wrist and elbow, and adduction of the arm, will allow of the resection of at least two inches. In the case of the sciatic, it is actually possible to resect five inches, if the nerve is widely freed, the knee flexed, and the hip hyperextended. In the arm, if these limits are exceeded, we have not the slightest compunction in resecting as much as may be necessary of the humerus.

We would lay very great stress upon the superiority of end-to-end suture over all other methods in dealing with a divided nerve. In very rare cases anastomosis to another nerve may be justifiable, but in the present state of nerve surgery it should only be done with the clear understanding that an experiment is being performed. Flap operations are occasionally successful. As to grafts, in spite of the prominence which is given to them in text-books, we know of few cases—the records of which will stand investigation—in which a successful result has been obtained. Doubtless a successful technique will one day be discovered; at present it does not exist. From cases which we have observed, we think it possible that the nerve fibres grow into the graft, but meet with a hopeless barrier at its lower end. If this is so, a secondary resection at the lower end of the graft might prove successful; we have not had, so far, the opportunity of carrying this out. It is a question which might well be the subject of a series of animal experiments. At present we strongly hold that direct suture should be carried out at any cost in every case, or that the operation should be abandoned in favour of tendon transplantation or some other method of restoring function.

Suture.—The actual suture of a divided nerve is a simple matter, but it demands an accurate technique. It is essential that the nerve should be handled as little as possible, and that the cut ends should not be handled at all. The nerve being held by its fibrous portion, a suture of ordinary fine catgut is passed transversely through its substance a short distance above the ultimate point of section. The same suture is similarly passed through the nerve below the point of injury. With a Gillette blade, or a very sharp scalpel, the nerve is now divided as near to the point of injury as healthy fibres can be

expected. The end is then examined, and if the nerve bundles do not appear sufficiently normal, a further slice is removed, the nerve being always held by the part to be cut off. The suture is now drawn tight, so as to bring the cut ends into direct apposition. If considerable tension is anticipated, a second suture is passed at right angles to the first. In order to obtain apposition, the limb must of course be brought to that position in which the nerve is as slack as possible. With the finest obtainable catgut and very fine curved needles, separate sutures are now inserted to bring together the sheath of the nerve. As regards the depth to which these sutures should pass, we regard it as of more importance that they should have a secure hold than that they should be limited to the nerve sheath itself, which is sometimes far too delicate for security. From four to ten of these sutures may be inserted, according to the dimensions of the nerve.

It is of importance that the true relative positions of the proximal and distal portions should be preserved without rotation. In most cases, however, where the nerve has been totally divided by the injury, this will be largely a matter of surmise ; but in a composite nerve like the sciatic, it can always be obtained with a considerable approach to accuracy.

The Protection of the Suture Line.—This is a matter about which there is much difference of opinion. We ourselves always make use of pedunculated flaps of fat, or of the protection of adjacent muscles. By dexterous suturing, with perhaps a small longitudinal incision into an adjacent muscle belly, it is usually quite easy to remove a suture line from the area of scar ; and this is the method which we prefer. If this is impossible, there is usually no difficulty in turning a small flap of subcutaneous fat to form a sheath for the nerve. It is worthy of note that in several cases where we have used fat flaps for this and other purposes, and where we have had the opportunity of inspecting them at a later date, they have been found after a year or more to be intact and to form a permanent living protection. We have also explored old nerve sutures protected with Cargile membrane, and found this lying in the tissues as a loose foreign body ; for that reason we feel diffident as to its suitability for the purpose.

The muscles and fascia are then replaced and repaired with catgut sutures as carefully as possible, and the wound is closed without drainage, except in the case of large buttock wounds, where a tube is left in the upper part of the incision, and passing through the gluteus maximus, for twenty-four hours.

Relaxation of Tension.—The limb is now fixed by bandages or splints in such a position as to insure relaxation of the nerve. We rely chiefly upon bandages, as being more comfortable ; but an anterior splint may be necessary to keep the elbow extended in the case of an ulnar nerve. In the leg, the most effective method is to tie the foot to a waist-band by a loop of bandage drawn as tight as may be necessary ; in this way slight movements of the hip and knee are allowed in opposite directions, which greatly relieve the strain of the position without interfering with the relaxation of the nerve. Usually at the end of a week, and in difficult cases after ten days, all restraints are removed, and the patient is allowed to move his limb as he may wish. We find that this is a perfectly safe plan, for the stiffness resulting from the fixation will prevent him from undertaking any but the most cautious movements, whilst the strength of the suture line will be quite sufficient to withstand any voluntary stress to which he is likely to subject it. By the end of another week or fortnight the nerve itself will have stretched sufficiently to allow of full movements of the limb. We regard prolonged fixation as quite unnecessary, and very inimical to the recovery of the limb.

RECOVERY.

An injury to a peripheral nerve may be sufficient to destroy the vitality of the axon cylinders beyond its site, or it may only be sufficient to inhibit temporarily their conducting power. In the one case the whole of the distal portion of the nerve will die, and recovery can only occur by the complete Wallerian cycle. In the other, a simple recovery of function is all that is required. These two methods of recovery are sharply differentiated, and proceed on entirely different lines ; but it is always possible that an

injury, though insufficient to destroy the vitality of a nerve, may be sufficient to permanently prohibit a return of function, owing to the extent of the local degenerative changes which occur in the nerve and surrounding structures. In such a case it may be necessary to resect the damaged portion, in spite of the fact that a partial lesion is thus converted into a complete one.

In civil practice, nerves are frequently sutured in clean wounds a few hours after injury, before degeneration has had time to occur in the peripheral portion of the nerve. In military practice this does not occur, and it may be taken that the peripheral portion of the nerve has passed through the complete process of Wallerian degeneration before suture is attempted. This is in itself a very striking difference, and is sufficient to account for many of the discrepancies in observations made on civil and military cases.

Sensory Fibres.—The process of recovery after complete degeneration will be the same whether the recovery occurs spontaneously or after resection and suture. The axon cylinders will grow downwards from above into the degenerated peripheral sheaths, and the extent of their recovery may be traced by a sign of which we have made use from the earliest stages of our work, but which was first described by Tinel. Gentle tapping over the course of the nerve at a point to which recovery has reached produces a tingling sensation in its normal distribution. We have noticed an interesting and peculiar example of this sign in cases where we have anastomosed the peripheral end of an injured musculospiral nerve into the median: tapping on the back of the forearm produces tingling in the centre of the palm. As the axon cylinders grow downwards, both epicritic and protopathic forms of sensation have in our cases generally returned simultaneously. It is more common in civil practice for the protopathic sense to return at an earlier date. Once recovery has begun, the anæsthetic area rapidly contracts and disappears, though in the case of an ulnar injury it is remarkable how slowly the little finger recovers. We are speaking of the crude tests with brush and pin to which we have already referred. Compass sensation, and those finer forms of tactile appreciation which are essential to the full utility of a limb, are slow in their return. Many of these avenues of sense depend upon complex cerebral connections for their perfection, and it is to that region rather than to the peripheral nervous mechanism that we must look for their recovery.

Motor Fibres.—On the motor side, the first evidence of recovery that we have observed is a shortening of the period of relaxation after galvanic stimulation. This is followed by a quickening of contraction to the same stimulus. In our own observations, voluntary power returns in general before any response to faradism can be obtained. On this point we are at variance with other observers; but it is a question in which the personal equation of the observer must always prove a large factor. It is obvious that an observer who depends more upon mental suggestion will obtain different results from one who relies rather upon the strength of his batteries. It is at any rate certain that faradic response and voluntary power return almost simultaneously. But though these are the views we hold, we would sound one note of warning. There is nothing in which one is so likely to be deceived as in the recovery of the voluntary power to perform a given movement. It is probable that for months the enthusiastic masseuse has been endeavouring to get the patient to perform the movements typical of recovery; and the ingenuity which he will display in carrying out her wishes is remarkable. To many of these false movements we have already referred; but in addition to these, there is a large group dependent upon slight contractures. Thus, in paralysis of the musculospiral, where the hand has been kept dorsiflexed in irreproachable position, the extensor muscles tend to become slightly shortened, and the flexion of the wrist will now produce a very fair imitation of a true extension of the fingers. Similarly, a shortening of paralyzed flexors may enable the patient to flex his fingers by extending the wrist. Unusual connections of the tendons are another source of error; we at present have a patient with musculospiral paralysis who can extend the terminal joint of his thumb by means of the abductor brevis pollicis, that muscle having, in his case, its unusual insertion into the dorsal expansion of the thumb.

FUNCTIONAL RESULTS OF NERVE SUTURE.

Recovery of function in a nerve is an extremely complex process, and is by no means summed up as the down-growth of axon cylinders. It is true that until this has taken place no recovery of function is possible; but this recovery involves a re-education of the whole neuromuscular mechanism, of which this forms only a link. The actual histological recovery of the nerve will depend upon such factors as the time which has elapsed since injury, and the youth of the patient; but the recovery of function will depend upon the patient's energy, upon his mental alertness, and upon the skill with which his personal efforts are directed along proper channels. The prognosis of nerve suture is therefore a matter of great complexity, and the term 'recovery' is so relative as almost to cease to have a meaning. It is easy to define the 'clinical' course of a case, to follow the return of 'pin and brush,' and to obtain from the patient a certificate of 'recovery,' if this is all he requires. I have myself seen several cases in which the ulnar nerve was completely divided without causing any remark on the part of either the patient or his medical adviser. It is still more remarkable that in one of these cases the patient considered that he had a perfectly normal hand until, a year later, his attention was called to his condition; the hand immediately became perfectly useless.

Individual Nerves.—The prognosis will depend upon the complexity of the nerve itself and of the functions which it is expected to perform.

Musculospiral.—Suture of the musculospiral nerve gives results only exceeded by those of its branch, the posterior interosseous. It contains few sensory fibres, and those of little importance; and its function is the simple one of extension of the elbow, hand, and fingers. Most of its motor fibres will therefore reach their proper destinations, and will not be lost in sensory nerve endings. In a simple case of suture of this nerve, recovery, complete in every sense, is usually rapid and certain.

Ulnar.—The ulnar nerve, on the other hand, is a mixed nerve with an important sensory supply, whilst the muscles which it controls carry out the fine and complex movements of the hand. The chances of motor and sensory fibres reaching motor and sensory endings are far smaller than in the case of the musculospiral, whilst the recovery of the fine movements of the hand involves an amount of re-education which can rarely be obtained. Recovery of the ulnar nerve is therefore a slow and uncertain process. But it must be remembered that the number of people who make any separate use of their fingers is extremely small, and that except to these people an ulnar nerve is a luxury rather than a necessity. To the majority the loss of the ulnar nerve is a matter of no importance. To the watch-maker, the artist, the musician, it is probably an injury beyond repair.

Median.—Somewhere mid-way between these two nerves lies the median. Like the ulnar, it is a mixed nerve, and its fibres may miss their proper goal; it is, however, enormously 'overwired,' for above the elbow one-third of its fibres may be divided without any discoverable loss of function; whilst on the motor side it controls chiefly the large and entire movements of the hand. The prognosis of its suture has, in our cases, been fairly good, though it will be long before the finer forms of sensation return.

Sciatic.—In the leg we have found the prognosis very much better than we at one time thought it likely to be. The down-growth of the sciatic fibres has been much more rapid than could have been reasonably expected when one considers the distance over which they have to pass. In complete sutures at the middle of the thigh we have seen motor recovery begin within four months, and reach a very fair degree of power within the year. Its sensory fibres appear to be much slower in regenerating; but we regard sutures of the sciatic, even after resections of great extent, with considerable confidence.

A remarkable feature is the very perfect function of the leg in complete lesions of the sciatic nerve when the inevitable drop-foot is relieved by some simple spring device. Our patients appear to walk with perfect freedom and little fatigue, their chief trouble being the risk of injury to an insensitive foot.

ALTERNATIVE METHODS.

However perfect the technique of nerve suture may become, there will always be a residuum of cases of nerve injury to which it is not applicable, or in which for some reason recovery is not to be expected. In such cases we must fall back upon other methods, and it will be well to glance at the alternatives which are at our disposal.

Lower Limb.—In paralysis involving the lower limb it is almost always possible to compensate by some orthopædic appliance for the movements which are lost, for those involved are crude, and stability is of much greater importance than refinement of action. A boot with side-irons and an uplifting toe-spring provides an almost perfect substitute for the extensors of the foot, and even in the case of a completely divided sciatic nerve this simple appliance will enable a man to walk with little fatigue. Even in cases where the nerve has been sutured, it is almost always worth while to provide the man with such an instrument, that he may obtain proper exercise and maintain the nutrition of the limb during the period of recovery. Where the paralysis is likely to be permanent, it is worth while considering some internal method of support, such as tendon transplantation, or the introduction of artificial ligaments. The former is only applicable in cases where at least some of the muscles have escaped, but in injuries to the external popliteal nerve it may give brilliant results. In such a case the tendons of the tibialis posticus and flexor longus hallucis may be transferred to replace the paralyzed extensor muscles. In complete paralysis of the sciatic, Lange has furnished us with a very simple and effective method of supporting the foot by means of artificial ligaments of silk saturated with perchloride of mercury. We prefer the following modification of Lange's original formula. The silk is prepared by boiling in perchloride of mercury (1–1000), transferring to an alcoholic solution of perchloride (1–1000), and finally preserving in parolein. The silk, which should be a thick floss, must be passed actually through the bones which it is desired to approximate. Special holes are drilled for this purpose, and four or more strands of silk are used. Silk, so prepared, does not tend to cause suppuration, and in a few months it becomes converted into an inextensible structure indistinguishable from tendon.

Upper Limb.—In the case of the arm the problem is far more difficult, and all that can be done is to support the joints whose movements are affected in such a way that the remaining muscles may act to the best advantage. In the case of a paralyzed deltoid, the supra- and infraspinatus may hypertrophy to such an extent that they can abduct the arm satisfactorily; but if this is not the case, it is better to erase the shoulder-joint and obtain a bony ankylosis in an abducted position. This is also the best method of dealing with an irremediable paralysis of the flexors or extensors of the elbow. This disability, however, rarely occurs, for as a rule some portion of the triceps will retain its power, and even if the biceps and brachialis anticus are both paralyzed in a lesion of the musculocutaneous nerve, the supinator longus furnishes a very efficient flexor of the joint. Of course, if a satisfactory transplantation of tendon can be performed, the retention of the mobility of the joint is a distinct advantage; but it is a great mistake to sacrifice the function of the limb for the sake of that of the joint; and as regards the usefulness of the arm to the patient, we certainly feel much greater confidence in the simpler, if less ambitious, method of ankylosis.

In a musculospiral paralysis, the patient's most serious disability is the weakness of his grasp, owing to the want of fixation of the wrist. This can largely be remedied by the application of a small cock-up splint which only occupies the palm and does not interfere with the mobility of the fingers. We have also devised a glove, in which tapes represent the dorsal tendons, whilst a powerful elastic accumulator, which lies on the forearm and is attached above the elbow, furnishes the necessary extending force.

In the region of the wrist the transference of tendons has given excellent results, and the extensors of the wrist, fingers, and thumb may be replaced respectively by the pronator radii teres, flexor carpi ulnaris, and flexor carpi radialis. It is only rarely, however, that such operations will be required.

CONCLUSIONS.

In these brief notes we have attempted to sketch our own experiences in one of the most complex and difficult fields of surgery, in the hope that they may be of some slight assistance to those who, like ourselves, are groping for the solution of the many problems it affords.

One lesson has been so driven home to us, that, before we conclude, we should like to impress it upon others. Success in nerve surgery is a matter of organization. The investigation of the cases is so complex, the operations involve such unusual details of experience and technique, and the after-treatment required is so tedious and varied, that only by means of an extensive organization can they all be satisfactorily carried out. The highest operative skill is of no use in the face of incompetent physico-therapy, whilst the most perfect physical treatment is powerless to remedy the mistakes of a clumsy surgeon.

We would plead earnestly for the concentration of all nerve cases in centres where they will have at their disposal the extensive material resources, the clinical experience, and the trained patience without which their recovery is a matter of chance ; and we would plead for routine and for simplicity in such a centre. Without routine, the department will rapidly degenerate into chaos ; without simplicity of method, the routine examination and treatment of any considerable number of cases become physically impossible.

Our own nerve cases are entered on the lists of a special department at the earliest possible moment after they enter the hospital. A careful examination is made and recorded as soon as the patient is so far recovered as to enable it to be carried out. This examination is repeated once a month, and meanwhile he is every day under the close observation of the department until he leaves the hospital. After that an attempt is made to keep in contact with the man himself or his medical adviser. Only in this way is it possible to keep the continuous records upon which alone the man's treatment can be scientifically founded. Only thus can we prevent the formation of contractures, which may mean permanent and unnecessary disability. Only by such close observation can we choose the psychological moment for operation.

Hanging on the wall of the department is a large chart on which is entered the monthly examination of every patient. In a journal is given an exact account of his monthly progress, sensory, motor, and electrical. He is given a card on which are entered the details of his treatment for the coming month, and on the card is daily recorded each treatment which he receives ; whilst his regular attendance for treatment is encouraged by a system of privileges. Each examination is conducted in the simple but complete manner which we have already described ; anything less would be of little value ; anything more would be exhausting to the patient and overwhelming to the investigator.

In operating, the surgeon should follow a simple and precise routine. He should have as clear and accurate a knowledge as is possible of the anatomy of the region, and of the condition of the nerve which he may expect to find. He should have a clear idea of what he means to do, and he should do it in the simplest manner possible.

The physical treatment of the case, before and after operation, should be based on a definite routine, although it should be directed to the special requirements of the patient, and should introduce all variety that is possible.

In short, the patient should feel that he is surrounded by a powerful organization, skilfully directed to his cure ; and it should be the aim of the surgeon to make that organization so perfect, that a man may be supported, through the tedium of many months, by the knowledge that his cure is its inevitable result.

APPENDIX A.

TABLES OF NERVES TREATED.

In the following tables the nerves which we have treated are grouped under five classes, as follows :—

1. Followed to complete recovery. In a military hospital only a few cases can come under this class.

2. Recovering normally, and likely in normal time to reach *Class* 1. As far as possible we have retained our cases until we had positive evidence that they belonged to this class.

3. Recovery doubtful or delayed. It is hoped that many of these cases will recover; but we had to part with them before we could be certain that this would be the case.

4. Total failures, after observation for at least a year. We do not expect these cases to recover.

5. Cases which we have not been able to follow up. In the Percentage Results this class is excluded.

It is to be noted that cases with multiple nerve lesions will appear in more than one table.

	Class 1. Recovered	Class 2. Recovering	Class 3. Doubtful	Class 4. Failures	Class 5. Unknown	Total
1. Sutures.						
Ulnar	1	12	—	1	5	19
Median	—	7	2	—	2	11
Musculospiral	1	3	—	—	1	5
Posterior interosseous	1	—	1	—	1	3
Brachial plexus	—	1	2	—	—	3
Sciatic, internal popliteal	2	4	—	—	2	8
Sciatic, external popliteal	2	5	2	—	2	11
Musculocutaneous	—	—	—	1	—	1
Total sutures	7	32	7	2	13	61
2. Neurolysis						
Ulnar	3	2	1	—	—	6
Median	1	3	—	—	—	4
Brachial plexus	1	8	—	—	—	9
Sciatic, internal popliteal	1	1	—	—	—	2
Sciatic, external popliteal	1	2	—	—	—	3
Total neurolysis	7	16	1	—	—	24
3. Anastomosis.						
Ulnar	—	1	—	—	—	1
Median	1	—	—	—	—	1
Musculospiral	—	2	—	1		3
Total anastomosis	1	3	—	1	—	5
Total Operations	15	51	8	3	13	90
4. No Operation.						
Ulnar	6	1	—	—	5	12
Median	2	2	1	—	3	8
Musculospiral	8	2	1	—	2	13
Posterior interosseous	2	—	—	1	—	3
Brachial plexus	—	2	—	—	—	2
Sciatic, internal popliteal	2	3	—	—	4	9
Sciatic, external popliteal	4	3	—	—	4	11
Total No Operations	24	13	2	1	18	58
Total of All Nerves	39	64	10	4	31	148

PERCENTAGE RESULTS OF CASES WHERE RECORDS ARE AVAILABLE.

	RECOVERED	RECOVERING	DOUBTFUL	FAILURES	TOTAL
Sutures	14	68	14	4	100
Neurolysis	29	67	4	—	100
Anastomosis	20	60	—	20	100
All Operations ..	20	66	10	4	100
No Operations ..	60	33	5	2	100
All Nerves	33	55	9	3	100

APPENDIX B.

ABSTRACTS OF CASE HISTORIES.

The following abstracts are intended to furnish, in the briefest possible space, a complete record of the work upon which this paper is founded. By examining them it is possible for anyone to ascertain the exact value which may be attached to the statements we have made and the opinions we have expressed. We trust that they will at least be found to be in accordance with the material upon which we have worked, and which we here produce.

The cases were under the charge of Captain L. E. C. Norbury, R.A.M.C., Captain A. Wills, R.A.M.C., Captain R. H. Campbell, R.A.M.C., Captain C. H. L. Harper, R.A.M.C., Captain W. Martin, R.A.M.C., and ourselves. In each case where an operation was performed the operator is indicated by his initials. For all observations and records we must accept the sole responsibility.

The following abbreviations have been used :—

R = Right. L = Left. V P = Voluntary Power. R D = Reaction of Degeneration. F = Faradism. G = Galvanism. P U = Permanently Unfit. SUMMARY = Summary of progress after operation.

ULNAR NERVE (OPERATED CASES).

Case 1.—*Feb.*, 1917.—Wound middle of R forearm. *March.*—Wound healed. Pressure upon it causes tingling in little finger. V P present in adductor of thumb and abductor of index, which react to F, but are sluggish to G. Other hand muscles of ulnar group have no V P, and show complete R D. Anæsthesia to wool and pin over distal segments of little finger. *April.*—Hypothenar muscles show small degree of V P. Wasting in third and fourth spaces, and clawing of little finger recovering. *Aug.*—All forms of sensation, except compass, present. *Oct.*—V P in all the ulnar group, which react to F, sluggish to G. Scar still tender to pressure. Operation advised. *Nov.*—OPERATION (W. M.). Ulnar nerve exposed in middle of forearm, and freed from adhesions. A fibrous nodule, resulting from partial division, found on its inner aspect. This was dissected off, without cutting deeply into nerve, and flap of fascia wrapped round it. *Jan.*, 1918.—V P (weak) in all hand muscles. Compass defective in little finger. No other sensory loss.

SUMMARY.—(11 *months*) *Almost complete recovery.*

Case 2.—*Jan.*, 1916.—Wound inner side of R elbow, fracture of inner condyle. Complete paralysis of ulnar nerve. *May.*—OPERATION (H. S. S.). Resection of ½ in. dense fibrous scar in nerve. Direct suture. Branch to flexor carpi ulnaris not divided. *July.*—V P in flexor carpi ulnaris. R D and no V P in other ulnar muscles. *April*, 1917.—Sensation recovering. V P in adductor pollicis. *May.*—No loss to wool, pin felt radiating. *Sept.*—Power recovering in all small muscles, and all react to F. *June*, 1918.—Doctor reports continued recovery.

SUMMARY.—(8 *months*) *Sensation recovering.* (10) *Power in abductor pollicis.* (16) *Power in all small muscles, sensation almost normal.*

Case 3.—*Oct.*, 1916.—Wound middle of R forearm. Partial fracture ulna. Ulnar paralysis. *March*, 1917.—Wound healed. Pressure causes pain in ulnar area. Complete ulnar paralysis of hand. Flexor tendons adherent, contracture of wrist. *July.*—Contracture reduced by splint. Complete wrist-drop, and loss of all movements of muscles of forearm, except flexors of thumb and index. All these muscles respond well to F. Ulnar hand muscles still show complete R D. *Jan.*,

1918.—Very slight power in portion of hypothenars only. Slight protopathic sensation in outer ulnar area. Total loss in little finger and adjacent hand. *March.*—Operation (H. S. S.). Explored. Nerve found almost completely divided, though conducting F to all muscles weakly. Resection suture over 2-in. gap. *May.*—Complete sensation in ring finger, probably overlap. Normal loss in remainder of ulnar area.

Case 4.—*July*, 1916.—Small wound front of R wrist. Partial lesion of ulnar. *Oct.*—Weakness of all interossei. Fair power in adductors of thumb, slight numbness in ulnar area. Operation (H. S. S.). Anterior part of nerve found divided. Posterior part conducted F. Fibrous part excised, and nerve protected from scar by fat sleeve.

Case 5.—*July*, 1916.—Large, deep wound involving whole of inner side of L forearm. Complete lesion of ulnar. *Oct.*—Wound closed by graft. Complete ulnar anæsthesia, and paralysis with R D ulnar hand muscles. Claw hand. *March*, 1917.—Operation (H. S. S.). Ulnar nerve exposed in forearm, 6 in. densely fibrosed ; did not conduct to F. On section no fibres visible. Distal end carried across forearm, between deep and superficial flexor tendons, and implanted into inner side of median. No interference to conduction of F by median resulted. *April*, 1917.—V P all median muscles. Sensory loss. *Nov.*—No evidence of recovery. *June*, 1918.—Doctor reports power and sensation returning.

Summary.—(14 *months*) *Power and sensation returning.*

Case 6.—*Sept.*, 1916.—Small perforating wound L arm, just below axilla. *Oct.*—Numbness in ulnar border of L hand, with some pain in this region. V P lost in ulnar muscles. Complete loss to pin and wool in ulnar area. *Nov.* 4.—Pain shooting in character. Ulnar sensitive to pressure at elbow. Thrill and expansile pulsation at wound over brachial. Operation (H. S. S.). Aneurysmal varix, with well-marked communication between vein and artery. Pressure on ulnar nerve, which was flattened, thick, and fibrous. Vein adherent to median and ulnar nerves. Fibrous tissue and recent blood-clot around vessels. *Nov.* 7.—Complete recovery, all forms of sensation and V P in 3 days. *Dec.*—Discharged fit for duty.

Summary.—(3 *days*) *Complete recovery.*

Case 7.—*Feb.*, 1917.—Wound inner side of L arm, just above elbow ; fracture of humerus. Ulnar paralysis. *April.*—Wound healed. Ulnar anæsthesia. Pressure on ulnar at elbow produces radiating pain in fingers. No V P and complete R D in ulnar muscles. *May.*—Operation (R. H. C.). Almost complete anatomical division at bend of elbow. Resection 1½ in. Nerve dislocated and sutured directly. *Aug.*—Doubtful V P in flexor carpi ulnaris. No return of sensation. Transferred to Warrington.

Case 8.—*May*, 1917.—Perforating wound inner side middle of R forearm. Ulnar paralysis. *June.*—Paralysis, and R D in ulnar hand muscles. Fingers contracted from fibrosis in wound. *Aug.*—Operation (W.M.). Complete division. Direct suture, from 1-in. gap. *Sept.*—Transferred to Dartford.

Case 9.—*Oct.*, 1916.—Large wound flexor surface R forearm. Fractured ulna. Ulnar paralysis. *Feb.*, 1917.—Operation (R. H. C.). 3½ in. nerve found completely destroyed. Bridged by flap method, junction buried in muscle fibres. *May.*—Pressure on nerve 2 in. below line of suture causes tingling in ulnar distribution. Discharged P U. *Nov.*—Reports considerable recovery of sensation. No treatment. *June*, 1918.—Letter from patient. States has had no treatment, thinks there is a little further improvement.

Summary.—(6 *months*) *Considerable sensory recovery.*

Case 10.—*July*, 1916.—Large wound front of R forearm. Fractured ulna and destruction of muscles on inner aspect. Complete ulnar paralysis. *March*, 1917.—Paralysis complete. Wound sound. Operation (H. S. S.). Nerve found completely divided, and 3½ in. missing. Proximal end cut across under biceps, and implanted into radial. Distal end carried beneath superficial flexors, and implanted into radial, which was cut across at both points. (*Figs.* 281, 282.) *April.*—Sensory loss in ulnar and a large radial area. R D all ulnar muscles. *Jan.*, 1918.—No sign whatever of recovery. *June.*—Doctor reports no evidence of recovery.

Summary.—(12 *months*) *No evidence of recovery.*

Case 11.—*Aug.*, 1916.—Wound across front of R wrist, involving ulnar nerve. *Oct.*—Wound healed. Complete ulnar paralysis. *March*, 1917.—Operation (H. S. S.). Ulnar found completely divided, two end bulbs, with 1½ in. gap. Gap closed by transplant from radial, doubled. *July.*—Sensation recovering. No return of V P. *Aug.*—Transferred to Warrington.

Summary.—(4 *months*) *Commencing sensory recovery.*

Case 12.—*Sept.*, 1916.—Small wound inner side of L upper arm. Paralysis of ulnar and internal cutaneous. *Nov.*—Operation (H. S. S.). Ulnar dissected out of dense fibrous tissue. Fibrous swelling. Internal cutaneous completely divided. Fibrous portion 1½ in. excised from each. Direct suture. Fat sleeve. *July*, 1917.—Slight recovery of sensation in area of both nerves. V P present in flexor carpi ulnaris. Other muscles R D, and no V P. *Oct.*—Function as before. Ulnar sensitive to pressure just below elbow. Above, nerve thickened and insensitive. *Jan.*, 1918.—Doubtful V P in flexor carpi ulnaris. No other change. Nerve still sensitive 3 in. below elbow. *April.*—Massage sister reports sensation recovered to web of fingers, general movements of

hand much improved. F response in flexor carpi ulnaris, flexor profundis digitorum, abductor minimi digiti, flexor minimi digiti ; none in interossei. *June.*—Doctor states ulnar recovering.

SUMMARY.—(12½ *months*) *Nerve sensitive to pressure in forearm.* (18) *Advanced recovery sensory and motor.*

Case 13.—*July*, 1916.—Wound L forearm. Fractured ulna. Complete paralysis ulnar nerve. *Nov.*—Complete paralysis, sensory and motor. R D hand muscles. OPERATION. Nerve explored. Complete division found. Fibrous part excised. Direct suture. *Sept.*, 1917.—No recovery of power or sensation. OPERATION (L. E. C. N.). Nerve explored. Fusiform thickening distal end.

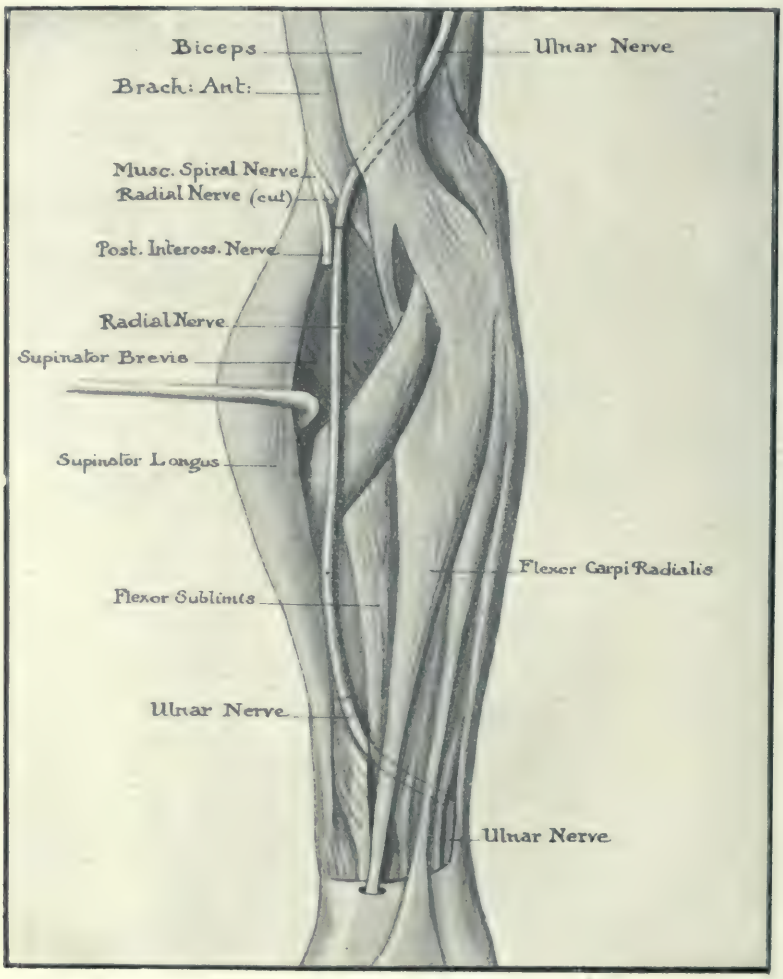


FIG. 281.—Use of the radial as a graft for the ulnar, without displacement of the former. (*Anatomy*) *Case* 10.

No end bulb on proximal end, fibres of which spread out in a fan, and attached to thickening on lower end. Resection of 1¼ in. Direct suture of apparently healthy ends. No conduction observed to direct F, and no evidence of recovery. *Jan.*, 1918.—Tingling on pressure 1 in. above pisiform. *April.*—Slight recovery small muscles of hand.

SUMMARY.—*After second operation* (10 *months*) *Commencing recovery in small muscles of hand.*

Case 14.—*March*, 1917.—Wound L forearm, inner side near elbow. Ulnar paralysis. Also penetrating wound of R parietal region of skull, with paralysis of L arm, which was recovering five weeks later. *May.*—Complete ulnar anæsthesia, and paralysis of ulnar hand muscles, with R D. *Sept.*—OPERATION (R. H. C.). Explored. Complete division found in upper forearm, with two end

bulbs. These were removed, and gap of 2 in. bridged by dislocating nerve to front of forearm, after division of humeral head of flexor carpi ulnaris. Buried in muscle. *Nov.*—Slight V P in flexor carpi ulnaris.

Case 15.—*July*, 1916.—Wound R forearm. Fractured ulna. Paralysis. *Sept.*—Ulnar anæsthesia. R D ulnar hand muscles. *Nov.*—OPERATION (H. S. S.). No conduction. Resection suture. *Nov.*, 1917.—Sensation recovering.

SUMMARY.—(12 *months*) *Some sensory recovery.*

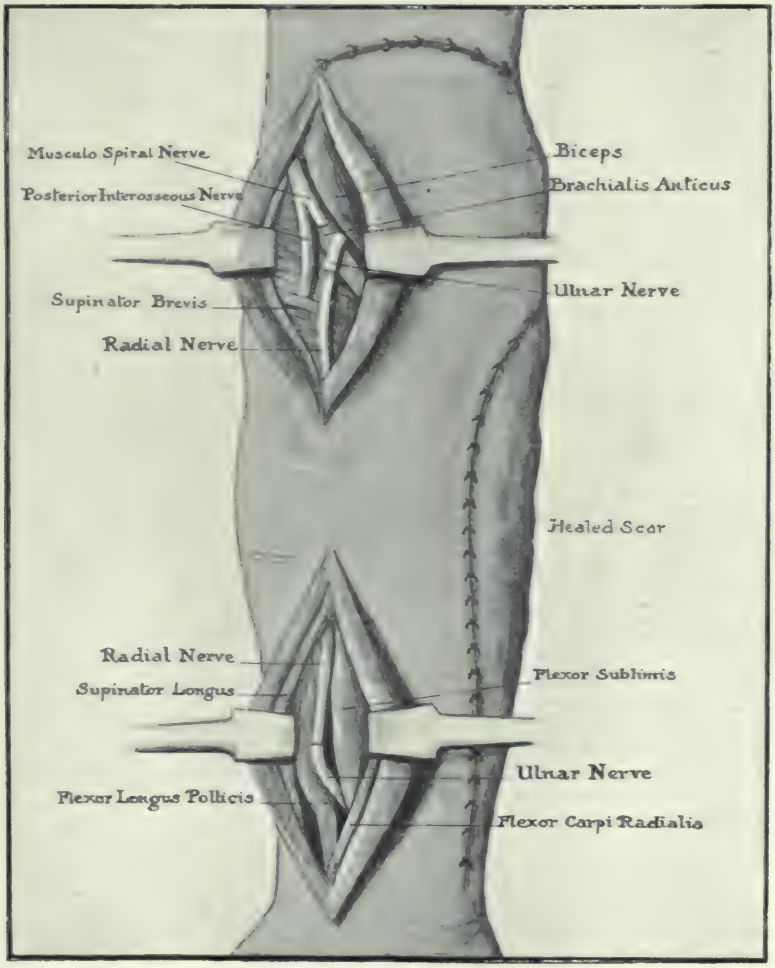


FIG. 282.—Use of the radial as a graft for the ulnar, without displacement of the former. (*Operation*) *Case* 10.

Case 16.—*July*, 1916.—Wound inner side R forearm. Compound fractured ulna. Paralysis ulnar nerve. *Oct.*—Wound healed at middle of ulnar border of forearm. Complete ulnar anæsthesia, with loss of power. R D in hand muscles. *Nov.*—OPERATION (H. S. S.). Nerve showed small hard bulb near scar. Stimulation with F above this gave no response, but below the bulb stimulation made hypothenars contract. Bulb resected ½ in. Direct suture. A few fibres could be seen to traverse bulb. *July*, 1917.—Recovery of protopathic all except little finger. No recovery of V P. *Oct.*—Sensation recovering. Chilblain over tip of little finger covers only area of protopathic loss. *Jan.*, 1918.—Sensation complete, except little finger. No recovery of motor power.

SUMMARY.—(8 *months*) *Extensive sensory recovery.* (12) *Sensory recovery almost complete, no motor recovery.*

Case 17.—*July*, 1917.—Small perforating wound R arm, above internal condyle. Paralysis ulnar nerve. *Aug.*—Wound healed. Complete ulnar paralysis, motor and sensory, with R D. *Sept.*—Operation (H. S. S.). Dense fibrosis in nerve closely limited to point of injury. Resection of ½ in. exposed healthy fibres. Direct suture. Nerve gave no reaction to F. *Jan.*, 1918.—Touch partially felt at base of ulnar area. Pressure on nerve does not produce tingling. A hard tender nodule felt at point of anastomosis. *April.*—Good V P in flexor carpi ulnaris. Sensation recovering.

Summary.—(6 *months*) *Sensory recovery commencing.* *Power in flexor carpi ulnaris.*

Case 18.—*Nov.*, 1916.—Small perforating wounds inner side R upper arm. Complete ulnar paralysis. *Jan.*, 1917.—Ulnar and internal cutaneous anæsthesia. Flexor carpi ulnaris shows weak V P, and reacts to F. Ulnar hand muscles no V P, complete R D. *March.*—Operation (H. S. S.). Ulnar found divided, embedded in dense adhesions, no conductivity to F. Excision of fibrous ends left 1½-in. gap, closed by direct suture. Internal cutaneous not seen. *July.*—Ulnar sensitive at elbow, slight sensory recovery. Internal cutaneous largely recovered. *Oct.*—Ulnar sensitive at wrist. *Jan.*, 1918.—Ulnar sensation commencing to return. Pin and touch complete in internal cutaneous, but localization defective. Power of forearm muscles good. No recovery in hand muscles.

Summary.—(4 *months*) *Nerve sensitive at elbow.* (8) *Nerve sensitive at wrist.* (10) *Sensory recovery commencing.*

ULNAR NERVE (CASES NOT OPERATED.)

Case 19.—*June*, 1917.—Wound L forearm. Fractured ulna. Ulnar paralysis. *July.*—Partial ulnar anæsthesia, partial paralysis hand muscles; all of which act normally. *Sept.*—Sensation recovered, including compass. Good power in ulnar muscles. *Oct.*—Complete recovery.

Summary.—*Complete recovery in* 4 *months from injury.*

Case 20.—*May*, 1917.—Wound L wrist. Complete ulnar paralysis of hand. Compound fracture femur. Discharged Australian hospital.

Summary.—*Transferred without operation.*

Case 21.—*Oct.* 1916.—Septic wound back of L forearm. Paralysis ulnar nerve. *Dec.*—Complete ulnar paralysis in hand, with R D and anæsthesia. *Feb.* 1917.—Anæsthesia recovered. Slight V P in hypothenars only. *April.*—Pin felt, except over last two joints of little and ring fingers. Slight power all hand muscles. *Jan.*, 1918.—Complete recovery.

Summary.—*Complete recovery* 4 *months from injury.*

Case 22.—*Feb.*, 1917.—Accidental fracture L radius and ulna, clean wound on flexor surface, middle of forearm. *April.*—R D and no V P ulnar hand muscles. Partial ulnar anæsthesia. *June.*—V P present all hand muscles. Sensation returning. *Sept.*—Nerve completely recovered.

Summary.—*Complete recovery* 7 *months from injury.*

Case 23.—*June*, 1916.—Wound L forearm. Fractured radius. Ulnar paralysis. *Nov.*—Complete motor and sensory paralysis, with R D. Transferred to Canadian hospital.

Summary.—*Transferred without operation.*

Case 24.—*June*, 1916.—Wound inner side L elbow. Ulnar paresis and anæsthesia. *Sept.*—Sensation almost entirely recovered. Weak V P in all muscles. Discharged.

Summary.—*Complete recovery* 3 *months from injury.*

Case 25.—*Sept.*, 1916.—Large wound inner side of R arm above elbow. Fractured humerus. Ulnar paresis. *April*, 1917.—Ulnar, internal cutaneous, and partial median anæsthesia. V P, and normal electrical reactions in all muscles. *June.*—Power improving. Sensation still impaired in ulnar area. *Aug.*—Discharged P U.

Summary.—*Incomplete recovery* 12 *months from injury.*

Case 26.—*Nov.*, 1916.—Wound R forearm, inner side of wrist. Amputation R foot. *Feb.*, 1917.—Complete ulnar paralysis in hand. *July.*—No recovery. Discharged to Brighton.

Summary.—*Transferred without operation.*

Case 27.—*Sept.*, 1916.—Large wound inner side of L arm above elbow. Ulnar seen to be divided, 2 in. missing. *Nov.*—Complete ulnar and internal cutaneous paralysis, with R D. *Feb.*, 1917.—Transferred to Taplow.

Summary.—*Transferred without operation.*

Case 28.—*Aug.*, 1916.—Wound L arm. Fractured humerus, with large septic wound. *March*, 1917.—Complete ulnar paralysis. Ankylosis of elbow. Bone united with large amount of callus. *April.*—Partial ulnar anæsthesia. V P ulnar hand muscles. Ulnar nerve conducts to F, to hand muscles. 2nd dorsal interosseous reacts to F. Others nil to F or G. *Aug.*—Recovery of protopathic, but not epicritic, over whole ulnar area. V P slight in all ulnar hand muscles. *Sept.*—Epicritic completely recovered. Good V P. Complete bony ankylosis of elbow, in useful position. *Oct.*—Complete recovery. Discharged P U, on account of elbow.

Summary.—*Complete recovery* 15 *months from injury.*

MEDIAN NERVE (OPERATION CASES).

Case 29.—*April*, 1917.—Deep, excavated wound over front of L wrist, radial side. Median nerve destroyed. *June.*—Wound healed. Above it bulb is felt, very tender and giving radiating pain in median area. Median anæsthesia in hand, with paralysis of small median muscles. *July.*—Operation (H. S. S.). Complete division of nerve, with large end bulb, and 1¼-in. gap. Flap turned down, with partial amputation of bulb, and sutured to distal end. (*Figs.* 283, 284.) *Oct.*—Pressure over lowest point of flap causes radiating pain in fingers. *Jan.*, 1918.—No recovery. Bulb appears to be forming at end of graft which gives radiating pain on pressure.

Summary.—(6 *months*) *Recovery to distal end of graft, with formation of bulb. Second operation to be performed.*

Case 30.—*May*, 1917.—Wound L arm just above elbow. Median paralysis. *June.*—Anæsthesia in most of median area. Back of index hypersensitive. Paralysis, and R D all median muscles. *Sept.*—Some V P all median muscles except opponens. Sensation unchanged. *Oct.*—Some recovery of sensation. V P condition unaltered. *Nov.* 16.—Operation (H. S. S.). Median freed from adhesions in antecubital fossa. Dense adhesions, small fibrous nodules in nerve, which could not be excised. Longitudinal incisions made in nerve. Pedunculated fat flap. Nerve conducted F forearm only. *Nov.* 22.—Sensation unchanged. Hypersensitive back of index. *Dec.*—Discharged to Australian hospital.

Case 31.—*Dec.*, 1915.—Wound middle of L arm. Fractured humerus. Median paralysis. *Aug.*, 1916.—Slight V P in median muscles, which react to F. *Nov.*—Wound healed. No further recovery. Median anæsthesia. *Dec.*—Operation (H. S. S.). Indurated portion of nerve resected. Direct suture. *Feb.*, 1917.—No recovery. Transferred to Cheltenham. *Nov.*—Doctor reports apparently no recovery.

Summary.—*No recovery in* 11 *months.*

Case 32.—*Aug.*, 1917.—Wound below middle of L forearm. Wound excised at C.C.S. same date, and primary suture of median performed. *Oct.*—Sub-total median anæsthesia. Paralysis, and R D in flexor longus pollicis and median muscles of thumb. Operation (H. S. S.). Nerve found in continuity, but fibrosed at suture line, and very friable. End-to-end suture, after resection of 1¼ in. Sections showed that no nerve fibres traversed the old suture line. *April*, 1918.—Pin produces radiating tingling at base of index and middle fingers, and over terminal portion of thumb.

Summary.—(6 *months*) *Protopathic sensation returning.*

Case 33.—*June*, 1915.—Bullet perforated R wrist. Median anæsthesia in hand. *Aug.*—No improvement. Operation. ½ in. fibrous nodule resected. Direct suture with silk and Cargile membrane. Intense bursting pain in fingers, severe pain along course of nerve in arm and forearm. Nerve tender to pressure. *Nov.*—Median nerve exposed in middle third upper arm, 15 min. 90 per cent alcohol injected. Temporary relief, but pain in few weeks severe as ever. *March*, 1916.—Operation (H. S. S.). Nerve explored at wrist. Fusiform junction found surrounded by dense sleeve of fibrous tissue, which could, however, be dissected off. Silk sutures and Cargile membrane unaltered. They were removed. They appeared to have acted as foreign bodies, and lay free from connection with the fibrous tissue which surrounded them. As much fibrous tissue as possible removed, but nerve not resected. It was hoped that it was regenerating. Buried under muscle. No relief in symptoms resulted. *May.*—Operation (H. S. S.). Exposed. Freed from fibrous tissue. Nerve three times normal diameter for 6 in. above injury, and densely fibrous. Split longitudinally. Saline injected into proximal end. Improvement followed, but only lasted few days. *Aug.*—Operation. Exposed. 3 in. thickened and fibrous. Excised. Gap of 2½ in. filled by radial graft, 3½ in. Result, immediate cessation of all pain. *Jan.*, 1917.—Sensation commencing to recover. Discharged to duty at own request.

Summary.—(5 *months after last operation*) *Sensation recovering.*

Case 34.—*July*, 1916.—Small wound front of R wrist. Median paralysis. *Oct.*—No V P. Complete R D short median muscles. Unusually small area median anæsthesia, limited to fingers 1 and 2. *March*, 1917.—Operation (H. S. S.). Complete division found. Two bulbs of 1½ in. gap. Suture by bulb-flap operation. (*Figs.* 283, 284.) *April.*—Sensory loss as before. *May.*—Extensive recovery, no loss to wool, pin blunted. *June.*—Transferred to Ireland. *Nov.*—Reports no treatment, and no recovery. *June*, 1918.—Reports fingers still numb.

Summary.—(2 *months*) *Extensive sensory recovery apparently not maintained.*

Case 35.—*July*, 1916.—Small wound centre of R forearm. Median paralysis. *Jan.*, 1917.—Protopathic loss only, R index and middle fingers. Paralysis, but no R D median forearm muscles. R D in opponens. Operation (R. H. C.). Median exposed, did not conduct. Excision of fibrous portion with direct suture. *Feb.*—Slight increase in area of sensory loss. *Nov.*—Reports power in forearm and sensation returning.

Summary.—(10 *months.*) *Commencing motor and sensory recovery.*

Case 36.—*July*, 1917.—Wound R axilla. Ligature axillary artery and vein. *Sept.*—Severe causalgia with tenderness in palm of hand three days after wound. *Oct.*—Pain better. Healed. *Nov.*—Hyperæsthesia median area, to all forms of stimulation, with anæsthesia median fingers, front and back. Skin red and mottled. Paresis median forearm muscles, thumb wasted, doubtful V P, R D. *Nov.* 16.—OPERATION (H. S. S.). Much scar tissue in axilla, involving wide excision. Median and ulnar explored to their origins from cords. Median harder than normal, some neuritis; no lesion of sheath was seen, and it was readily shelled out from scar tissue. Conducted F to all muscles. Ulnar normal. *Dec.*—Hyperæsthesia in median area. Power improving. Pain

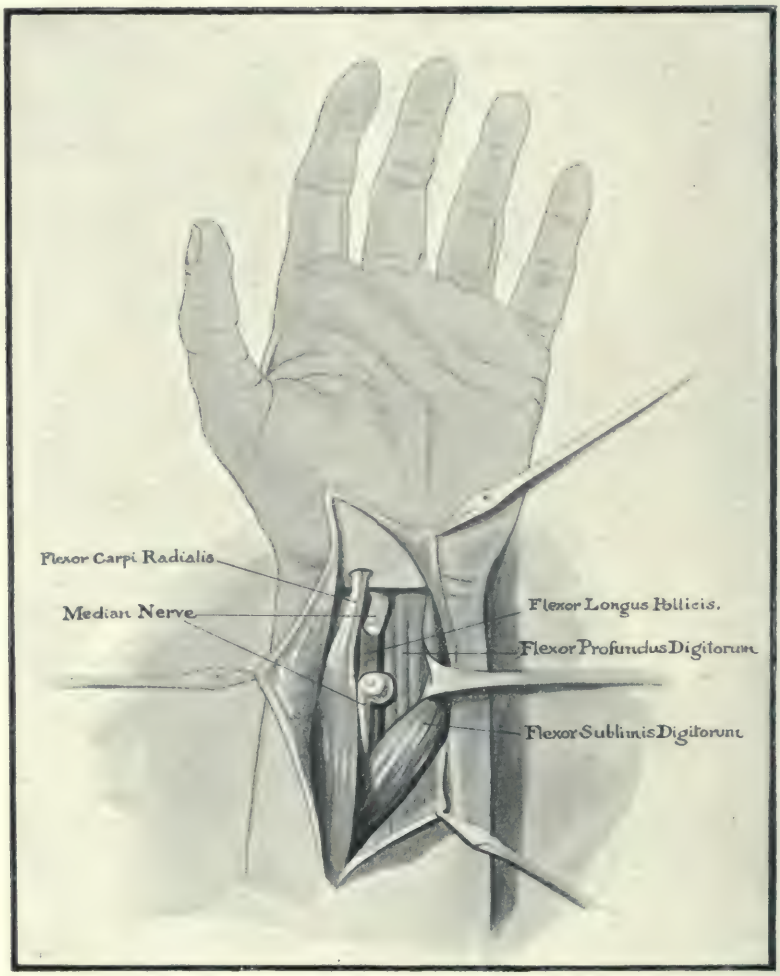


FIG. 283.—Bulb-flap operation, applied to the median. (*Step* 1) *Cases* 29, 34.

relieved by weak sinusoidal baths. *Feb.*, 1918.—Opponens and abductor have V P, but are wasted. *April.*—Pain has disappeared. Condition of arm improving, and muscles recovering power. *July.*—Almost completely recovered.

SUMMARY.—(1 *month*) *Reduction of pain, improvement in power.* (8) *Recovery almost complete.*

MEDIAN NERVE (CASES NOT OPERATED).

Case 37.—*April*, 1917.—Large wound back of L forearm. Fractured radius. Wrist drop. *June.*—Wound not quite healed. Union of radius incomplete. Muscles of forearm very weak, but wrist-drop disappeared. Anæsthesia to wool in median area. V P and F response in all

median muscles, except flexor longus pollicis. *July.*—Median area hyperæsthetic to pin. Power in median muscles poor. *Aug.*—Sensation recovering. V P in flexor longus pollicis. Transferred to Warrington.

SUMMARY.—*Recovering satisfactorily 4 months after injury.*

Case 38.—*April*, 1917.—Several small wounds L upper arm, one small fragment lying on median nerve removed. *May.*—Hyperæsthesia in median and internal cutaneous areas. No V P in opponens or flexor sublimis. Other muscles fair. *Sept.*—Hyperæsthesia same area, but less

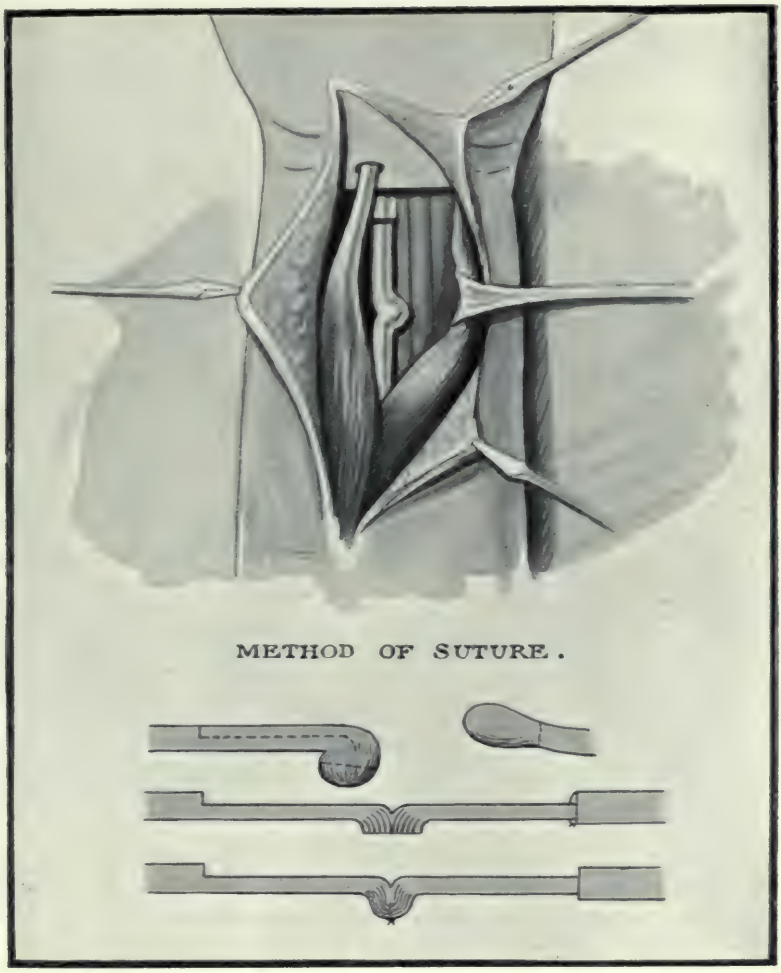


FIG. 284.—Bulb-flap operation, applied to the median. (*Step* 2) *Cases* 29, 34.

marked. Grip good, except with index. R D and no V P in opponens. Discharged Canadian hospital.

SUMMARY.—*Transferred without operation.*

Case 39.—*Jan.*, 1917.—Bullet perforated inner side L arm above elbow. Brachial artery tied for hæmorrhage. Median paralysis. *April.*—Numbness in middle and index fingers. Weak V P in median muscles, which react sluggishly to G, and not to F. *July.*—Median area feels numb, but is hyperæsthetic to pin. Power improving. Transferred.

SUMMARY.—*Recovering satisfactorily 6 months after injury.*

Case 40.—*Aug.*, 1916.—Wound L arm above elbow. Complete median loss of power and sensation, with R D. *March*, 1917.—Operation refused. No recovery. Discharged.

SUMMARY.—*Operation refused.*

Case 41.—*Oct.*, 1916.—Small multiple wounds R upper arm. *March*, 1917.—All wounds healed. *X* ray shows many fragments of metal around humerus. Internal cutaneous anæsthesia. Blunting to pin middle finger back and front. Pressure on median site of scar causes burning pain in middle finger. Wasting not marked, median fingers glossy. No V P flexor sublimus, longus pollicis, opponens, and abductor. R D of all these. Partial R D flexor carpi radialis and palmaris longus. Pronator radii teres no R D. *May.*—Middle finger hypersensitive to pin at front, blunt on dorsum. V P present all median muscles. *Sept.*—Middle finger still hypersensitive. Cannot completely flex index. Median muscles still weak; react to F, sluggish to G.

SUMMARY.—*Recovery poor* 12 *months after injury.*

Case 42.—*July*, 1916.—Large wound inner side R elbow. Median paralysis. *Aug.*—Partial median paralysis, some V P in flexor carpi radialis and opponens only. R D all median muscles. No loss to pin in median area, but brush imperfectly felt. *Sept.*—All median

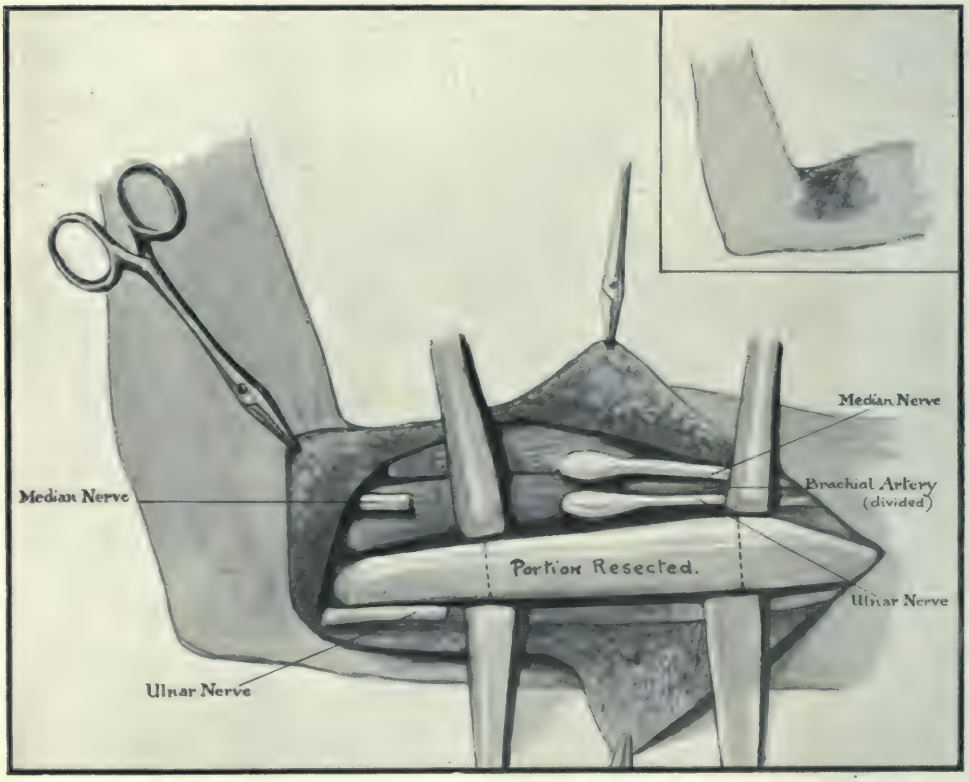


FIG. 285.—Median and ulnar injury. Resection of the humerus to obtain approximation. (*Step* 1) *Case* 48.

muscles, except flexor longus pollicis, recovering V P. *Nov.*—Complete recovery, sensory and motor. *June*, 1918.—Reports recovery.

SUMMARY.—*Complete recovery* 4 *months after injury.*

ULNAR AND MEDIAN NERVES (OPERATION CASES).

Case 43.—*July*, 1916.—Large through shell wound of L upper arm. Complete ulnar and partial median loss. *Aug.*—Severe causalgic pain in median area of L hand. *Oct.*—Alcoholic injection into median. Relief of pain, and total loss of median followed. *March*, 1917.—Still complete paralysis of median and ulnar nerves. OPERATION (L. E. C. N.). Nerves exposed in upper arm. Both looked degenerate, were fibrotic, but not completely divided. The median, much thinned at site of injection, gave way during stretching with a view to resection. It was impossible to bridge the gap, so the upper and lower ends were implanted laterally into the ulnar. *Nov.*—No evidence of recovery. *Jan.*, 1918.—Patient can flex wrist and fingers slightly, and appears to have some V P in all flexors of forearm. Some irregular sensory recovery in median

area. *April.*—Complete median sensory recovery. Good V P in all muscles of forearm except flexors of index and thumb. *May.*—V P flexors of index and thumb. All muscles of forearm respond briskly to G. Ulnar flexors respond to F.

SUMMARY.—(10 *months*) *Considerable recovery.* (12) *Complete median, extensive ulnar, recovery, sensory and motor.*

Case 44.—*May*, 1917.—Bullet pierced R upper arm inner side, cutting brachial artery. Complete median and partial ulnar paralysis, motor, and sensory. Total R D in median, incomplete in ulnar. *July.*—Recovered all forms of ulnar sensation, complete median anæsthesia. Feeble flexion in ulnar forearm muscles alone. All muscles give R D. *Oct.*—Feeble V P in ulnar and median forearm muscles. Area of anæsthesia diminished. *Jan.*, 1918.—No further improvement. Arm therefore explored. OPERATION (L. E. C. N.). Ulnar shelled out of dense fibrous tissue; conducted F to forearm. Median densely fibrosed, and did not conduct. 1½ in.

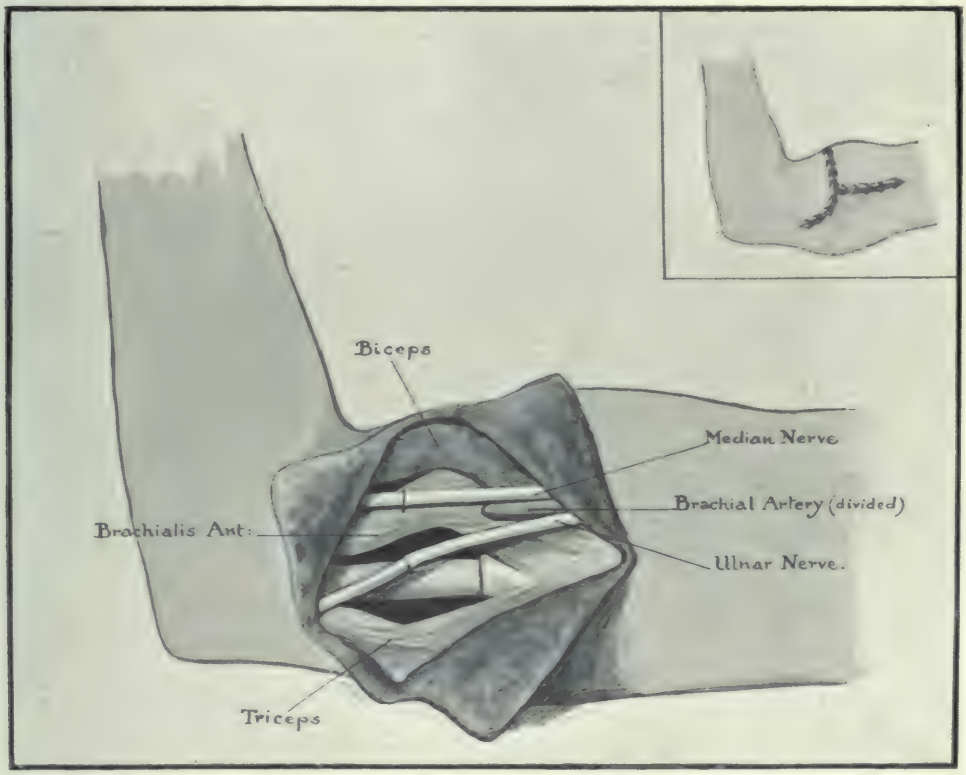


FIG. 286.—Median and ulnar injury. Resection of the humerus to obtain approximation. (*Step 2*) *Case* 48.

resected, end-to-end suture. *March.*—Good power in ulnar muscles of forearm. R D in all small muscles of hand. Total median paralysis. *April.*—Ulnar hand muscles respond to G stimulation of ulnar at wrist. *June.*—Anæsthetic area greatly diminished. Fair V P in ulnar muscles and in flexor profundus digitorum. *July*—Anæsthesia limited to terminal joints of index.

SUMMARY.—(4 *months*) *Ulnar recovery in forearm.* (6) *Advanced sensory recovery, complete in ulnar.*

Case 45.—*July*, 1917.—Bullet pierced L upper arm at middle of inner side. Complete sensory and motor paralysis of ulnar, median, internal cutaneous; except that pronator radii teres has entirely escaped. *Nov.*—OPERATION (R. H. C.). On exploration, ulnar found completely divided, and was sutured. Median was involved in scar, and thickened and indurated for 1 in. Conducted F to forearm muscles, but not to flexor longus pollicis, or to hand. It was freed only. *June*, 1918.—Sensation and V P recovering in both median and ulnar. (Report from Capt. Broad, Alder Hey.)

SUMMARY.—(8 *months*) *Recovery, sensory and motor, in both nerves.*

Case 46.—*Aug.*, 1916.—Large wound R arm, much destruction of tissue, Median sutured and brachial artery tied at C.C.S. *Sept.*—Median and ulnar anæsthesia, R D in muscles, but slight V P in flexors of wrist and fingers, none in hand muscles. *March*, 1917.—Anæsthesia as before, slight V P in flexor carpi ulnaris and profundus; no reaction to F or G in other muscles. OPERATION (H. S. S.). Total division of median, 2-in. gap, sutured. Ulnar thinned at scar, but conducted F to above muscles. Wrapped in fat. *April.*—Discharged to London. *Nov.*—Reports no treatment, and no recovery.

SUMMARY.—(8 *months*) *No recovery.*

Case 47.—*March*, 1917.—Wounds of flexor surface of L elbow, and middle of L forearm. Brachial artery ligatured upper wound. Complete ulnar and doubtful median paralysis. *May.*—Complete ulnar paralysis hand only, partial median paralysis. *July.*—Healed. Fair power median forearm muscles, none in flexor longus pollicis, or in hand muscles. *Aug.*— OPERATION (H. S. S.). Median exposed in upper wound, and freed, surrounding scar tissue excised. Both nerves exposed in lower wound. Complete division of ulnar, with 2-in. gap, bridged by flap method. Median not obviously damaged, but did not conduct F. *Sept.*—Condition unaltered. *June*, 1918.—Doctor reports ulnar sensation recovered, except in phalanx of little finger. Movements of thumb improving.

SUMMARY.—(10 *months*) *Ulnar sensation recovered.*

Case 48.—*July*, 1916.—Inner side R arm above elbow blown away. Brachial artery tied in France. *Aug.*—No V P in median and ulnar nerves; complete R D in muscles. *Nov.*—OPERATION (H. S. S.). Nerves exposed. Complete division found, with 3 in.-gap. As this could not be closed, 3 in. of humerus were excised, the resect being used as a medullary peg. Median and ulnar nerves sutured directly, but not internal cutaneous. (*Figs.* 285, 286.) *April*, 1917.—No change in anæsthesia. Slight V P in flexors and pronators. Pressure on ulnar nerve 3 in. below suture causes radiating pain in ulnar area of hand. *June.*—V P in all forearm muscles, median and ulnar. Pressure on median 4 in. above wrist and ulnar on wrist, causes characteristic radiating pain. *Sept.*—Good V P wrist and fingers. Pressure on median at wrist causes radiating pain. Sensation largely recovered. Forearm flexors react to F slightly. *Oct.*—Wool felt half-way down palm, pin to middle of second segments of fingers. Good reaction in forearm to F. Hand muscles as yet show no recovery. *Jan.*, 1918.—Protopathic recovery to ends of fingers. V P in all forearm muscles, none in hand. Fingers held in phalangeal flexion, but can be readily straightened.

SUMMARY.—(6 *months*) *Commencing recovery.* (8) *Advanced recovery, sensory and motor.* (12) *Complete recovery except in small muscles of hand. Full power in forearm.*

Case 49.—*July*, 1916.—Bullet perforated inner side R arm just below elbow. A week later, radial ligatured for hæmorrhage. *Aug.*—Slight V P in flexors of forearm. *Oct.*—Median and ulnar anæsthesia. Slight V P in all muscles of forearm and hand; hand muscles do not react to F. *Feb.*, 1917.—Condition unaltered. OPERATION (R. H. C.). Stimulation of ulnar and median nerves by F caused contraction of all forearm but no hand muscle. Nerves freed from dense scar tissue, and wrapped in fat. *April.*—Improved power in forearm muscles. *May.*—Discharged P U. *Nov.*—Reports complete recovery of sensation median area, none in ulnar, and recovery of power in flexor muscles. *June*, 1918.—Doctor states forearm less wasted. Interossei improving. Great improvement in flexion. Extension of wrist and fingers. All muscles, except interossei, respond to F.

SUMMARY.—(10 *months*) *Recovery of median sensation. Power in forearm muscles.* (16) *Complete recovery, except in small muscles of hand.*

Case 50.—*July*, 1916.—Bullet perforated inner side of R arm above elbow. At first partial median anæsthesia, severe pain in hand. As pain diminished, anæsthesia extended. *Sept.*—Complete paralysis, motor and sensory, median, ulnar, internal cutaneous. R D in all paralyzed muscles. *Nov.*—Slight V P in all forearm muscles, but R D in all. No recovery of sensation. *Feb.*, 1917.—No further improvement. OPERATION (H. S. S.). Ulnar and median embedded in dense mass of scar tissue. No conduction of F in ulnar. Median conducted F slightly to forearm muscles only. Excision suture of both, 2 in., with forward dislocation of ulnar. *July.*—Ulnar sensitive at elbow. Slight V P in flexors of forearm, median and ulnar. *Oct.*—Pin can be felt in palm as low as web. Some recovery to pin in dorsal branch of ulnar. Power improving. Pressure on ulnar at palm causes radiating pain in fingers. *Jan.*, 1918.—Sensation rapidly recovering. Good V P in all muscles of forearm. *March.*—V P in all muscles except thumb. Sensation recovered except in little finger.

SUMMARY.—(6 *months*) *Motor recovery in forearm.* (8) *Sensory recovery to web of fingers.* (12) *Recovery complete except in small muscles of hand.*

MEDIAN AND ULNAR NERVES (CASES NOT OPERATED).

Case 51.—*Jan.*, 1917.—Two large wounds inner side of R arm and forearm. Brachial artery tied. Median and ulnar paralysis. *April.*—Complete median and ulnar paralysis, with R D. *June.*—Transferred to Carlisle.

SUMMARY.—*Transferred without operation.*

Case 52.—*July*, 1916.—Bullet perforated R arm, just below elbow. Ligature of brachial. Painful median and ulnar anæsthesia, with paralysis in all muscles. *Nov.*—Forearm muscles react to F. R D in hand muscles. *March*, 1917.—V P in forearm muscles, and all muscles of hand except adductors of thumb. Sensation recovering. *May.*—Sensation almost entirely recovered. V P in all muscles. Reactions normal.

SUMMARY.—*Almost complete recovery* 10 *months after injury.*

MUSCULOSPIRAL NERVE (OPERATION CASES).

Case 53.—*May*, 1917.—Perforating wound outer side of upper arm below middle. Complete musculospiral paralysis, except triceps. *June.*—Anæsthesia external cutaneous, and radial area. R D in all paralyzed muscles. *Sept.*—OPERATION (R. H. C.). Nerve exposed in groove through posterior incision. 1½ in. excised, and ends joined by direct suture. *Nov.*—No change. Reaction to G sluggish, but good volume, muscles in good condition. *June*, 1918.—Doctor states patient can flex and extend fingers and wrist slightly; grip greatly improved.

SUMMARY.—(9 *months*) *Recovery advanced.*

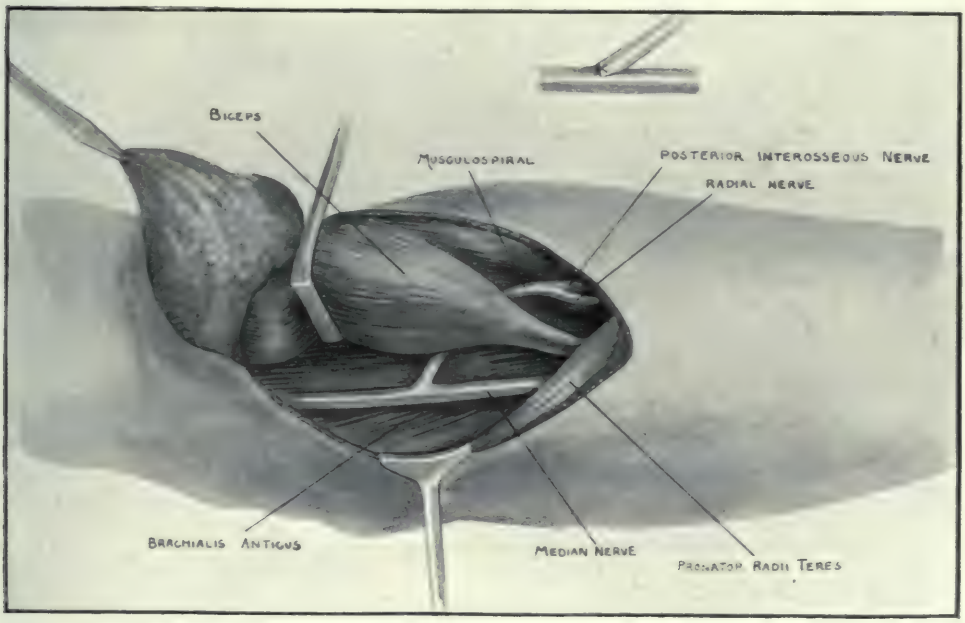


FIG. 287.—Anastomosis of paralyzed musculospiral with median. *Cases* 54, 56, 59.

Case 54.—*Sept.*, 1916.—Badly lacerated compound fracture upper third R humerus. Complete musculospiral paralysis, except long head of triceps. *March*, 1917.—Bone united with large mass of callus. Sinus led down to sequestra. To remove these, bone opened up freely, one side of cavity being completely removed. No V P in musculospiral below wound, and complete R D. *Oct.*—OPERATION (H. S. S.). Nerve exposed and traced to tunnel in bone, where both proximal and distal ends terminated in fibrous bands, with a gap of 3½ in. Lower end was therefore anastomosed to centre of front of median, fibres of which were here divided. (*Fig.* 287.) *Nov.*—Slight paresis of pronators, flexor carpi radialis, and sublimis. No loss of power in thumb muscles, no sensory loss. A little pain referred to middle fingers. *Jan.*, 1918.—Definite tingling in palm, on pressure over musculospiral 2 in. below anastomosis. *May.*—Tingling now felt from lower third of forearm. No V P or F response. *July.*—F response in extensors of wrist.

SUMMARY.—(4 *months*) *Nerve sensitive below suture.* (8) *Sensitive in lower third of forearm.* (10) *F response returned.*

Case 55.—*July*, 1916.—Fracture middle of L humerus. Wrist-drop. *Oct.*—Anæsthesia radial area on dorsum of hand. Complete paralysis, with R D of all musculospiral muscles except triceps. *Nov.*—OPERATION (H. S. S.). Nerve exposed, and found completely divided, ends being joined by fibrous tissue in tunnel of callus. Resection with direct suture. *April*, 1917.—Slight numbness in radial area; no definite anæsthesia; no motor recovery. *May.*—Slight power

in extensors of wrist. *June.*—Fair power in supinators and extensors of wrist, slight V P in extensor communis and thumb extensors. *Aug.*—V P extensor indicis. Reactions of all muscles weak to G, nil to F. *Sept.*—Extensor carpi ulnaris reacts to F. *Oct.*—Good V P in all muscles which react to F. Limb almost normal in appearance and power.

SUMMARY.—(6 *months*) *Slight power of extension of wrist.* (8) *Power in all extensors.* (10) *Reaction to F first obtained.* (12) *Complete recovery, return to duty.*

Case 56.—*June*, 1916.—Large wound back of R upper arm. Fractured humerus. *Sept.*—Bone united, wound still large. Doubtful V P triceps; complete loss, with R D, in all other musculospiral muscles. Wool anæsthesia external cutaneous and radial areas. *April*, 1917.—Triceps recovering. No reaction to G in extensors of forearm. External cutaneous recovered. Radial unchanged. *May.*—OPERATION (H. S. S.). Nerve exposed in axilla and beneath triceps. Branch to triceps intact. Main trunk fibrosed for 3 in., with end bulb. Direct suture considered impracticable. Nerve exposed through fresh incision under supinator longus, and median by horseshoe extension of incision. Musculospiral carried across arm between biceps and brachialis anticus, and implanted into median, antero-external fibres of which were cut. (*Fig.* 287.) Eight days later no loss of median power or sensation could be discovered. *Oct.*—No return of V P. Small area of radial anæsthesia. *Jan.*, 1918.—Tenderness to pressure on posterior interosseous 3 in. below elbow, tingling in median area of palm. Reactions brisk at motor points. *April.*—Synergic contraction of extensors on flexing fingers. *June.*—Grip powerful, and assisted by extensors, which have weak, independent V P, and react to F.

SUMMARY.—(8 *months*). *Nerve sensitive 3 in. below elbow.* (10) *Sensitive lower third of forearm. Slight power in supinator longus and radial extensors.* (12) *Strong synergic action of extensors of wrist, independent power improving.*

Case 57.—*July*, 1917.—Bullet pierced L arm, fracturing humerus below neck. Wrist-drop occurred at once. *Sept.*—Total musculospiral paralysis, excluding triceps. No reaction to F in paralyzed muscles, brisk response to G, marked galvanic tetanus. Partial anæsthesia on dorsum of thumb. *Oct.*—Typical R D in paralyzed muscles. OPERATION (H. S. S.). Nerve adherent to bony spur. Removal of spur exposed small cavity in bone, which was scraped out and filled with B.I.P.P. Upper end of nerve divided from scar, a branch to long head of triceps being inevitably divided at same time. Distal end in two portions and easily separated from scar. These two portions and nerve to triceps directly sutured to proximal end. Brachial artery involved in scar, and was ligatured during separation of nerve. *Jan.*, 1918.—No change. No power in triceps, which shows R D. *March.*—Weak V P in triceps, other muscles react briskly to G, not to F. *May.*—Distal tingling on pressure above external condyle.

SUMMARY.—(6 *months*) *Power in triceps. Nerve sensitive at elbow.*

Case 58.—*July*, 1916.—Large wound, antero-external aspect of R elbow, tissues destroyed down to bone. Complete musculospiral paralysis below wound. *March*, 1917.—Still complete paralysis, with R D. OPERATION (H. S. S.). Nerve found divided at bend of elbow, with large end bulb, and gap of 3 in. below as far as supinator brevis. Posterior interosseous exposed in supinator brevis, hard, fibrous, and wasted. No conduction to F. Muscles supplied by this nerve pale, and responded feebly to direct F. Bulb removed, end-to-end suture, with elbow flexed. *Oct.*—No definite V P. Reaction to G brisker and of better volume. *Feb.*, 1918.—Slight V P in extensor carpi ulnaris. *July.*—Fair power in extensors of wrist and fingers.

SUMMARY.—(10 *months*) *Slight power in extensor carpi ulnaris.* (16) *Recovery in all muscles.*

Case 59.—*Jan.*, 1915.—Wound L arm. Severe fractured humerus. Paralysis of musculospiral nerve. *Nov.*—OPERATION. 4 in. of nerve missing, graft of internal cutaneous introduced. *Jan.*, 1917.—No evidence of recovery. Total sensory loss in internal cutaneous and radial areas. Triceps normal, other muscles R D. No V P. OPERATION (H. S. S.). No trace of graft discovered. Distal end exposed, gave no reaction to F. Brought under biceps and implanted into median on anterior aspect, a third of the fibres being divided. (*Fig.* 287.) *Feb.*—Sensory loss in small median area. Loss of V P in flexor longus pollicis and opponens. All other median muscles intact. *July.*—Recovery of sensation in median area. Slight V P in flexor longus pollicis. *Jan.*, 1918.—No evidence of musculospiral recovery, though reactions to G somewhat brisk. Complete median recovery.

SUMMARY.—(12 *months*) *No recovery.*

Case 60.—*Nov.*, 1917.—Transverse wound back of L upper arm, near deltoid insertion. Wrist-drop. *Jan.*, 1918.—Paralysis of supinator longus, and extensors of forearm, with R D. Anæsthesia in an exceptionally large radial area. Paresis of median and ulnar muscles, but all have V P. *April.*—OPERATION (W. M.). *Resection suture.*

Transferred.

MUSCULOSPIRAL NERVE (CASES NOT OPERATED).

Case 61.—*Jan.*, 1917.—Wound L arm. Fracture lower end of humerus. Musculospiral paralysis. *May.*—Complete paralysis in forearm. Discharged to Ireland.

SUMMARY.—*Transferred without operation.*

Case 62.—*Sept.*, 1916.—Wound upper part of R arm. Fractured humerus. Musculospiral paralysis. *Feb.*, 1917.—V P in triceps, supinator longus, and long radial extensor; none in posterior interosseous. Incomplete R D in all except triceps. *July.*—Transferred to Cardiff.

SUMMARY.—*Transferred without operation.*

Case 63.—*Sep.*, 1916.—Fracture upper end L humerus. Musculospiral paralysis. *Feb.*, 1917.—Paralysis complete, except for triceps and supinator longus. *March.*—V P in radial extensors of wrist. R D and no V P in posterior interosseous muscles. *April.*—V P in extensor carpi ulnaris. *May.*—V P in extensor communis digitorum. *Aug.*—Complete recovery. Discharged to duty.

SUMMARY.—*Complete recovery* 11 *months after injury.*

Case 64.—*May*, 1917.—Wound R knee, and small wound outer side of R arm. Wrist-drop. *Sep.*—R D and no V P in musculospiral muscles below wound. *Nov.*—Has recovered fair V P. *March*, 1918.—Power much improved. Nil to F; G brisk at motor points. Slight numbness in radial area. *July.*—Complete recovery.

SUMMARY.—*Complete recovery* 14 *months after injury.*

Case 65.—*July*, 1916.—Two large septic wounds back of R upper arm. Musculospiral paralysis. *Aug.*—triceps reacts to F. R D in other muscles, with loss of V P. Sensory loss in musculospiral area on forearm. *Sept.*—V P extensors of wrist, thumb, index. V P in supinator longus and brevis. Nil to F in posterior interosseous. G brisk at motor points, sluggish over tendons. *Feb.*, 1917.—Power improving; all react to F. No loss of sensation.

SUMMARY.—*Advanced recovery* 7 *months after injury.*

Case 66.—*Aug.*, 1916.—Wound R arm. Fracture middle of humerus. Musculospiral paralysis. *Nov.*—Slight V P in triceps, and possibly supinator longus. R D and no V P in other muscles of group. *March*, 1917.—Recovering V P in all except deep extensors. *June.*—Fair power in all muscles.

SUMMARY.—*Advanced recovery* 10 *months after injury.*

Case 67.—*May*, 1917.—Two small punctured wounds upper part of L arm. Bruit over upper wound. Paresis of musculospiral. Immediate wrist-drop. *June.*—Small aneurysmal varix of superior profunda, slight numbness in radial area, and weakness of extensors; but all muscles react to F. *July.*—Power improving. Discharged to Australian hospital.

SUMMARY.—*Advanced recovery* 2 *months after injury.*

Case 68.—*June*, 1916.—Wound L arm. Fractured humerus. Wrist-drop. *July.*—Extensors of forearm react to F. *Aug.*—All muscles recovered V P. *Oct.*—Discharged with good power in all muscles.

SUMMARY.—*Recovery* 2 *months after injury.*

Case 69.—*July*, 1917.—Wound L arm. Fractured lower third humerus. Wrist-drop immediately. *Nov.*—Nearly healed, fracture united. Complete paralysis, with R D of musculospiral from supinator down. Radial anæsthesia to wool. *Jan.*, 1918.—Slight power radial extensors. Nil F. Loss to wool same area. Patient says he has more feeling. *April.*—Full power in all muscles, sensory loss as before.

SUMMARY.—*Complete recovery of power* 9 *months after injury.*

Case 70.—*April*, 1916.—Multiple wounds L forearm. Fracture radius and ulna, and musculospiral paralysis. *June.*—Complete paralysis below elbow, with R D, except that supinator longus reacts to F. *Oct.*—Slight recovery V P in extensors of forearm. Reactions brisker. *Dec.*—Complete recovery.

SUMMARY.—*Complete recovery* 8 *months after injury.*

Case 71.—*July*, 1916.—Wound L arm. Fracture upper third humerus. Complete loss of power in biceps, brachialis anticus, and all musculospiral muscles below triceps. *Aug.*—Paralysis and R D biceps and brachialis anticus. V P musculospiral group, though R D still persists. *Sept.*—Reactions in musculospiral group becoming normal. Biceps and brachialis anticus show R D and no V P. *Oct.*—OPERATION (H. S. S.). Musculocutaneous found divided and adherent to bone at point of entry to biceps. Resection suture. *Oct.*, 1917.—No recovery in musculocutaneous. Complete recovery musculospiral. Supinator longus so hypertrophied that flexion of elbow is normal.

SUMMARY.—*Complete recovery* 9 *months after injury.*

Case 72.—*July*, 1916.—Wound L arm, outer side above elbow. *Aug.*—R D and no V P in musculospiral muscles below point of injury. *Jan.*, 1917.—Recovering V P. R D still present. *Feb.*—Nerve conducts G, and muscles react briskly to G, but not to F. *March.*—Nerve conducts, and muscles react to F. V P good. *July.*—Complete recovery.

SUMMARY.—*Complete recovery* 12 *months after injury.*

Case 73.—*July*, 1916.—Small wound outer side L arm above elbow. Musculospiral paralysis *Sept.*—R D and no V P posterior interosseous. Supinator longus doubtful. *March*, 1917.—Weak V P extensors of wrist and fingers, not thumb. Electrical reactions unaltered. *June.*—

Little improvement. Slight power in extensor ossis metacarpi pollicis. Extensor muscles for most part react to F. *Dec.*—No improvement. *Jan.*, 1918.—Fair V P and F response, radius and ulnar extensors. No V P, and no F response communis, or short extensors.

SUMMARY.—*Poor recovery* 18 *months after injury.*

POSTERIOR INTEROSSEOUS NERVE (OPERATION CASES).

Case 74.—*April*, 1917.—Small perforating wound front of L elbow. Complete paralysis posterior interosseous. Perforating wound of R chest. *July.*—R D in posterior interosseous group and in extensors of wrist, and paralysis of all these muscles. *Sept.*—OPERATION (H. S. S.). Nerve explored. Complete fibrosis at origin of posterior interosseous. Nerve to extensor carpi radialis longior conducted F. 1¼ in. damaged nerve excised, with direct suture. Nerve reached in gap between extensor carpi radialis longus and supinator longus. *June*, 1918.—Report from doctor states that patient can extend wrist, but not fingers. Thinks he is improving.

Case 75.—*July* 1, 1916.—Bullet perforated L forearm transversely in front of bones. Wrist-drop. *July* 20.—Paralysis posterior interosseous group. All react to F except thumb extensors; and briskly to G. No anæsthesia. *Aug.*—R D in paralyzed muscles. *Oct.*—OPERATION (H. S. S.). Nerve exposed in supinator brevis. 1 in. densely fibrosed. Resected with direct suture. Did not conduct F. *April*, 1917.—Slight V P in extensors of thumb and extensor carpi ulnaris. All react briskly to G at motor points. *May.*—Fair V P in above muscles, slight V P in extensor communis. *July.*—Good V P in all muscles. Extensor communis and carpi ulnaris react to F, and briskly to G. Deep muscles sluggish. Discharged to duty.

SUMMARY.—(10 *months*) *Complete recovery.*

Case 76.—*July*, 1916.—Small wound back of R forearm. Extensors of thumb, and index paralyzed. *Nov.*—OPERATION (H. S. S.). Nerve exposed at point where it divided into several branches. Resection suture, with separate suture of each branch to proximal trunk. *May*, 1917.—No sign of recovery. Discharged P U.

POSTERIOR INTEROSSEOUS NERVE (CASES NOT OPERATED).

Case 77.—*June*, 1916.—Wound R elbow, fracture of humerus. Wrist-drop. *Aug.*—Complete paralysis, and R D in radial extensors and posterior interosseous muscles. *May*, 1917.—Nerve recovered, fair V P. *Sept.*—Complete recovery.

SUMMARY.—*Complete recovery* 13 *months after injury.*

Case 78.—*May*, 1917.—Wound L arm just above external condyle. Paralysis extensors of forearm. *June.*—Small healed wound just above L elbow. V P triceps, supinator doubtful, very feeble power in posterior interosseous muscles. Thumb extensors nil. No anæsthesia. F in triceps supinator longus only. G in paralyzed muscles fairly brisk. *Oct.*—V P supinator and radial extensor. No V P, R D posterior interosseous. *Dec.*—Posterior interosseous recovered. V P to all muscles. Nil to F. *Jan.*, 1918.—Good V P posterior interosseous. Numbness unchanged (radial area). *March.*—Perfect V P. Very slight numbness in radial area. Discharged to duty.

SUMMARY.—*Complete recovery* 10 *months after injury. Discharged to duty.*

Case 79.—*April*, 1917.—Large wound outer side upper L forearm. Fracture radius and ulna. Posterior interosseous paralysis. *May.*—Ulna plated in open wound. *July.*—Anæsthesia to pin in radial area. No V P in posterior interosseous or in radial extensors. *Sept.*—V P in radial extensors. No V P in posterior interosseous, and no reaction to F or G. Plate removed.

SUMMARY.—*Case unsuitable for operation. No recovery.*

BRACHIAL PLEXUS (OPERATION CASES).

Case 80.—*Jan.*, 1916.—Wound R axilla. Traumatic aneurysm axillary artery, which was ligatured. Extensive paralysis of arm followed, severe pain in hand and forearm. *Nov.*—Gross fixation of hand; has not responded to treatment. Pain present, but has gradually improved. Trophic changes very marked. Ulnar chiefly affected. OPERATION (H. S. S.). Nerves dissected out, both above and below clavicle, from dense scar tissue, and surrounded with fat. Nerves all reacted feebly to F. *Dec.*—Sensation recovering. V P in flexor carpi ulnaris. No pain. *June*, 1917.—Hand muscles recovering V P. Wool and pin felt everywhere, slightly blunted on ulnar border of little finger. Marked recovery in mobility of fingers and usefulness of hand.

SUMMARY.—(6 *months*) *Extensive recovery, sensory and motor.* (8) *Recovery almost complete.*

Case 81.—*July*, 1916.—Wound of R arm below shoulder. Fractured humerus. Arm felt dead below elbow at once. Next day intense pain hand and fingers. *Aug.*—Irregular hyperæsthesia and anæsthesia of hand. No V P in fingers. *Oct.*—Wasted, tremulous, purple hand. Drop-wrist. Pain shoots at night into ulnar fingers and thumb. Anæsthesia in these areas. *Oct.* 30.—Alcohol (5 min.) injected into upper and lower trunks above clavicle. Slight relief from pain followed for few days only. *Nov.*—Wound reopened. Injection of alcohol (30 min.) into all three trunks.

Pain reduced but not abolished. Hand held stiff and extended. Fingers became glazed, smallest movements cause great pain. *July*, 1917.—Entirely free from pain. Hand stiff, but healthy in appearance. Slight power in flexors of forearm. Sinus in upper arm still open. *Feb.*, 1918.—Fingers stiff and movements limited. Total paralysis of musculospiral. Sinus closed. *April.*—Operation (H. S. S.). Musculospiral sutured in axilla, with difficulty, over 2 in. gap. Nerve entirely destroyed.

Summary.—*Slow but progressive recovery until* (18 *months*) *suture of musculospiral.*

Case 82.—*July*, 1916.—Wound below L clavicle, passing upwards and backwards. Small perforating wound back of L forearm in upper third. Complete musculospiral paralysis, with anæsthesia to outer side of hand and forearm. *Aug.*—Paralysis and R D in whole musculospiral group except supinator longus, which has slight V P. Operation (H. S. S.). Fragment of shell removed from behind middle trunk of plexus. *Sept.*—V P and response to F in triceps, radial extensors; R D in posterior interosseous group. *March*, 1917.—Operation in view of no further recovery. Posterior interosseous explored. No direct damage found, but nerve looked degenerate and did not conduct F.

Summary.—(4 *months*) *Recovery of all put posterior interosseous group.*

Case 83.—*April*, 1917.—Punctured wound of L axilla. A fortnight later paralysis of musculospiral, and traumatic aneurysm axillary artery. This was excised on account of severe hæmorrhage. *July.*—Extensive plexus paralysis. Anæsthesia to elbow. Complete paralysis posterior cord and hand muscles. Weak V P in forearm. *Oct.*—Considerable sensory, but no motor recovery. *Nov.*—Operation (L. E. C. N.). Musculospiral and circumflex found completely divided, with end bulbs, and sutured. Median and ulnar freed from dense fibrous tissue. Both conducted F to forearm, but not to hand. Anæsthesia in ulnar, median, internal cutaneous, and radial area. *April*, 1918.—Sensory recovery in thumb and radial portion of hand. Complete paralysis of deltoid, triceps, and all musculospiral muscles. *June.*—Good V P in deltoid. Weak in supinator longus. None in triceps. Deltoid responds to F,; triceps brisk to G, nil to F. No further sensory recovery.

Summary.—(8 *months*) *Sutured nerves recovering.*

Case 84.—*Sept.*, 1915.—Wound R shoulder. Aneurysm third part of axillary artery. *Oct.*—Complete median and musculospiral paralysis, with anæsthesia and R D. *Dec.*—Operation (L. E. C. N.). Artery ligatured above and below aneurysm, sac excised. *July*, 1916.—Triceps and median muscles of forearm react to F. *Sept.*—Can extend wrist slightly. V P in triceps. Anæsthesia median and radial areas. *Feb.*, 1917.—V P supinator longus and extensor muscles of forearm, and median flexors. *April.*—Power all muscles except opponens. Sensation recovering in fingers. Discharged P U. *Nov.*—Reports considerable sensory recovery. *June*, 1918.—Doctor reports pronation and supination half normal. Flexion of wrist normal. Extension $\frac{3}{4}$. Sensation of hand returning, particularly on ulnar side. Movements of fingers improving.

Summary.—(6 *months*) *F reactions returning.* (10) *Power in triceps and extensors of wrist.* (14) *Power in all muscles of forearm.* (24) *Advanced recovery.*

Case 85.—*June*, 1915.—Perforating wound R axilla. *July.*—Total paralysis R arm. Biceps and extensors forearm respond to strong F. Other muscles no response to F or G. *Aug.*—Biceps and brachialis anticus show good V P. Triceps responds to strong F. Extensors forearm no response to F, faint to G. Severe aching pain in whole arm, complete sensory loss in forearm and hand. *Oct.*—No V P in any muscle in arm. Complete R D. Pain increasing. Operation (Maj. Nitch). Aneurysm first part of axillary dissected out, adherent to all nerves of plexus. Alcohol injected into nerves above lesion. No relief of pain followed. *Dec.*—Again explored. Musculocutaneous and inner head of median found divided, possibly in last exploration. Sutured directly. *July*, 1916.—V P in triceps, deltoid, supinator longus. Hyperæsthesia of arm to elbow, sensation returning in upper forearm. R D in all other muscles. *Dec.*—V P median flexors, and in all muscles of upper arm and supinator longus. Sensation recovered to wrist. No deep loss.

Summary.—(8 *months*) *Power in triceps, deltoid, supinator longus.* (12) *Steady progressive recovery.*

Case 86.—*June*, 1917.—Small penetrating wound below R coracoid, metal lodged under scapula. *July.*—Intense pain in hand. Anæsthesia outer border of arm, forearm, and thumb. V P present in pectorals and spinati, deltoid doubtful, none in biceps, triceps, or other muscles of arm, forearm, or hand. All nerves react to F except musculospiral. Pain relieved by ionization of brachial nerves. *Aug.*—Ulnar and median muscles recovering. *Oct.*—Deltoid improving. No V P in biceps or musculospiral group. *Jan.*, 1918.—V P in biceps. Lesion now equivalent to complete musculospiral. Operation (H. S. S.). Plexus exposed below clavicle, pectoralis minor being divided. Plexus dissected from dense mass of scar tissue. Musculospiral found divided. Circumflex arose just above division, and had to be divided in exposure of proximal of posterior cord. Direct suture of musculospiral and circumflex posterior cord. *March.*—Complete paralysis in posterior cord. Weak V P in biceps. *April.*—Good V P in all ulnar and median muscles. Weak reaction to F, and doubtful V P in deltoid. *June.*—Good power in all muscles except those of posterior cord, which all react briskly to G. Nil to F. *Aug.*—V P in deltoid, which reacts to F. Triceps brisk to G and reacts to F.

Summary.—(7) *Recovery of power in deltoid, triceps responds to F. Remainder of plexus has completely recovered.*

Case 87.—*July*, 1916.—Clean perforating wound below L axilla. No nerve lesion. *July* 14.—Traumatic aneurysm brachial artery. OPERATION (H. S. S.). Sac dissected out, vessel tied above and below. *Aug.*—Aching pain in head, worse at night. *Oct.*—Pain continuous. Extensive loss of sensation in region of ulnar areas. OPERATION (H. S. S.). Median and ulnar nerves dissected from dense fibrous tissue, and wrapped in fat. *Jan.*, 1917.—Pain entirely disappeared. Sensation recovering.

SUMMARY.—(4 *months*) *Extensive recovery.*

Case 88.—*April*, 1917.—Bullet traversed R posterior triangle, entrance in front just above clavicle, exit middle inner border of scapula. *May.*—Aching pain in hand, and tenderness of brachial plexus, with referred pain on pressure. No definite anæsthesia, but numbness of circumflex area and outer side of arm and forearm. No V P biceps, deltoid, supinator longus. Slight V P triceps and muscles of forearm. *June.*—Complete atrophy of deltoid and spinati, with loss of V P and R D. *July.*—OPERATION (H. S. S.). Plexus exposed above clavicle. Upper trunk scarred at junction of 5 and 6 cervical nerves. Freed from scar, and fibrous nodule in anterior aspect of trunk excised. Triceps alone reacted to F stimulation of this trunk. *Sept.*—V P in supinator longus hand and forearm good. No pain. *Dec.*—Slight V P in deltoid, biceps, brachialis anticus, supinator longus, but not sufficient to move elbow. No reaction to F. *Jan.*, 1918.—Power in these muscles improving, can flex elbow against gravity. *March.*—Good power in all muscles of arm, forearm, and hand. Movements slow.

SUMMARY.—(4 *months*) *Good power supinator longus hand and forearm.* (6) *Fair power in deltoid and flexors of elbow.* (8) *Good power in all muscles.*

Case 89.—*Sept.*, 1917.—Small wound of R neck, with fracture of 6th R transverse process. *Nov.*, 1917.—Intense causalgia palm of R hand, which is held rigidly semiflexed with thumb adducted into palm. Weak V P in all muscles, but slightest movements of arm cause intense pain. Flexor muscles of forearm respond feebly to F. Other muscles normal response. *Nov.* 11.—OPERATION (H. S. S.). Incision behind R sternomastoid. All cervical roots from 3 to 7, spinal accessory and phrenic nerves exposed in dissection. 5th root conducted normally to deltoid, biceps, supinator longus. 6th root gave no response. 7th root conducted forearm flexors, triceps, and extensors of forearm. 6th root swollen, and fragment of metal in contact with it. On attempting to dissect 6th root free, sac of small aneurysm of vertebral artery was torn, with profuse hæmorrhage. Artery tied close to origin, without result. Anterior portions of 5th and 6th transverse processes removed, and vessel tied above and below sac. Bleeding serious, and controlled with very great difficulty by this means. 5th cervical root injured in the operation. *Nov.* 23.—Pain entirely relieved. Movements of hand and flexors improved. Complete paralysis of 5th cervical nerve (biceps, deltoid, supinator longus, supra- and infra-spinati). *Jan.*, 1918.—V P in all muscles except biceps, deltoid, supinator longus, supra- and infra-spinati, which are wasted and show R D. Triceps very weak. Narrow area of anæsthesia radial border of forearm and hand. *April.*—Weak V P in deltoid and biceps. Good power in most other muscles. *May.*—Full V P in all muscles except supinator longus. Sensation recovered. *Aug.*—Good power in all muscles. No sensory loss.

SUMMARY (10 *months*) *Complete recovery.*

BRACHIAL PLEXUS (CASES NOT OPERATED).

Case 90.—*June*, 1916.—Wound above middle L clavicle. Empyema. *Sept.*—Paralysis and R D in supra- and infra-spinati, and deltoid, except for a few anterior fibres in last muscle. *Feb.*, 1917.—V P in deltoid. Discharged Carlisle.

SUMMARY.—*Deltoid recovered* 8 *months after injury.*

Case 91.—*Sept.*, 1916.—Wound of L axilla, followed by traumatic aneurysm, operation at station hospital two days later. *Dec.*—Wounds healed. Extensive paralysis brachial plexus. Deltoid shows fair power, triceps feeble, all other muscles in arm paralyzed. Anæsthesia below middle of forearm, except radial part of dorsum. Deltoid reaction normal. None in other muscles. *March*, 1917.—V P triceps, supinator longus, all extensors of wrist. No V P biceps flexors of wrist and fingers, extensors of fingers; supinator longus reacts to F. *April.*—V P in extensors of thumb. *July.*—Sensation returning. Almost complete recovery in biceps, supinator longus, extensors. No power in flexors of forearm or hand muscles. Ulnar sensitive at elbow. *Oct.*—Further recovery of sensation. V P in brachialis anticus. Great hypertrophy of supinator longus. *Feb.*, 1918.—Slight V P in flexors of wrist. Rubbing ulnar border of hand produces tingling.

SUMMARY.—*Very advanced recovery, except in hand,* 18 *months after injury.*

SCIATIC NERVE (OPERATION CASES).

Case 92.—*Sept.*, 1916.—Large wound R buttock. Sciatic paralysis. *Oct.*—V P in hamstrings. Complete paralysis other muscles, with R D. Small area of sciatic anæsthesia. *Feb.*, 1917. OPERATION (H. S. S.) Complete division found in buttock. Direct suture over gap of 2 inches. *May.*—Discharged P U for treatment.

Case 93.—*April*, 1917.—Perforated wound R thigh. Complete sciatic paralysis. *May.*—No

V P. Complete R D in muscles supplied by external and internal popliteal. Corresponding sensory loss. *Sept.*—No improvement. OPERATION (H. S. S.). Complete lesion of sciatic nerve at middle of thigh. 1½ in. replaced by dense mass of fibrous tissue, 1 in. diameter. Resection with direct suture. No conduction to F. External and internal popliteal could be identified, and were correctly apposed.

Case 94.—*Sept.*, 1916.—Transverse wound back of L thigh, 4 in. above knee. *Oct.*—Two operations for secondary hæmorrhage, followed by drop-foot. *Jan.*, 1917.—External popliteal paralysis, with complete R D and anæsthesia. Weak V P in calf muscles. *Feb.*—OPERATION (H. S. S.) Sciatic freed from dense fibrous tissue; both divisions showed old bruising on surface. Internal popliteal reacted strongly to F. External popliteal in peronei only. Wrapped in fat. *April.*—Good power in peronei. Slight power in extensors. Discharged. *June.*—Sensation recovered in whole external popliteal area. Fair power in all muscles of leg.

SUMMARY.—(2 *months*) *Good power peronei.* (4) *Sensation recovered. Fair power in all muscles.*

Case 95.—*July*, 1916.—Wound near head of R fibula. Foot-drop. *Aug.*—Paralysis, with R D, anæsthesia in external popliteal. *Oct.*—OPERATION (L. E. C. N.). Complete division found. Bulb. Direct suture over 1-in. gap. Cargile membrane. *May*, 1917.—Doubtful V P in peronei. Sensation almost entirely recovered. Brisk reactions to G. Discharged. *June.*—Doctor reports complete recovery of movement and sensation.

SUMMARY.—(8 *months*) *Sensation complete, weak power peronei.* (10) *Complete recovery.*

Case 96.—*Sept.*, 1916.—Small perforating wound back of L thigh. Sciatic paralysis. *Oct.*—Paralysis with R D in internal popliteal. Weak V P in external popliteal muscles. Corresponding sensory loss. OPERATION (H. S. S.). Internal popliteal found divided just below bifurcation. Bulbous ends united by strand of fibrous tissue. Direct suture over 2-in. gap. *July*, 1918.—Doctor reports recovery of protopathic sensation and of muscular power.

SUMMARY.—(8 *months*) *Sensation and power recovering.*

Case 97.—*Sept.*, 1916.—Perforating wound above middle of back of R thigh. Immediate pain in sole, numbness of foot. *Oct.*—Causalgia in sole, numb to wool. Mixed hyperæsthesia in external popliteal area. Recovering V P. Paralysis and complete R D in external popliteal. Alcohol injection into nerve 3 in. above lesion. Both divisions conducted F before injection. *Nov.*—Wound suppurated, pain not relieved. *Dec.*—Complete paralysis whole sciatic distribution, with R D and anæsthesia. No pain. *Feb.*, 1917.—OPERATION (H. S. S.). Internal popliteal found completely fibrous. Two inches resected direct suture. External popliteal freed. Dense perineural adhesions found round injected portion of nerve. *June*, 1917.—Slight power in peronei. *July.*—Slight power extensors of toes. *Aug.*—Pin recovering external popliteal area. Power improving. *Sept.*—Slight V P in calf muscles. *Nov.*—Fair power in calf, no reaction to F. *Jan.*, 1918.—External popliteal reacts to F. and power is good. Pressure on post tibial 6 in. above ankle gives tingling in sole. Fair power in calf muscles. Discharged.

SUMMARY.—(4 *months*) *Slight power in peronei.* (6) *Slight power in extensors.* (8) *Slight power in calf.* (12) *Good power in all muscles.*

Case 98.—*July*, 1916.—Perforating wound R thigh just below buttock. Paralysis R leg. *Aug.*—Paralysis external popliteal, with R D and anæsthesia. No V P in internal popliteal, no sensory loss. *Nov.*—Calf muscles recovering. *Jan.*, 1917.—OPERATION (R. H. C.). External popliteal found completely divided, two end bulbs. Resection suture. Internal popliteal conducted F. *April.*—Discharged. *Nov.*—Reports considerable recovery in sensation and power. *June*, 1918.—Some further improvement.

SUMMARY.—(10 *months*) *Sensation and power recovering.*

Case 99.—*Aug.*, 1916.—Large portion middle of back of R thigh blown away. No V P below knee. External popliteal anæsthesia. Internal popliteal partial anæsthesia, and paræsthesia. *Jan.*, 1917.—Complete R D below knee. *Feb.*—OPERATION (H. S. S.). Internal popliteal almost entirely divided, though a few fibres traversed scar. External popliteal completely divided. Resection suture both nerves. *May.*—Pressure on external popliteal at neck of fibula gives radiating pain to foot. *Oct.*—Slight V P in peronei and calf muscles. *Jan.*, 1918.—Fair power in calf. None in peronei or anterior tibial group, though pressure on nerve produces radiating pain as before. Some sensory recovery. *June*, 1918.—Doctor reports slight improvement in power. Walks fairly well.

SUMMARY.—(4 *months*) *Nerve sensitive neck of fibula.* (8) *Slight power in peronei and calf muscles.* (10) *Good power in calf.* (11) *Continued improvement; walking well.*

Case 100.—*June*, 1916.—Wound through middle of R thigh. Foot-drop, with slight anæsthesia dorsum of foot and toes. Pain in ball of foot. *Nov.*—Fair V P internal popliteal. None in external popliteal. No pain. External popliteal anæsthesia. OPERATION (H. S. S.). External popliteal found completely divided. Sutured. Internal popliteal slightly nicked, but conducted F well. Was not touched. Both nerves wrapped in fat. *April*, 1917.—V P in peronei. sensory recovery in all but small area on dorsum of foot. *July.*—External popliteal paralysis again complete; patient has been wearing garter for elastic foot support, and pressure has injured the nerve. *Aug.*—V P present in all external popliteal muscles. No sensory recovery.

Jan., 1918.—Good V P. No sensory recovery in external popliteal area. *June.*—Reports can walk satisfactorily with an instrument.

SUMMARY.—(4 *months*) *Power in peronei and almost complete sensory recovery.* (8) *Secondary injury, complete paralysis.* (12) *Advanced motor but no sensory recovery.*

Case 101.—*March*, 1917.—Wound lower third of L thigh. Fractured femur. *Sept.*—Fracture united, wound not healed. Paralysis external popliteal, incomplete anæsthesia. Internal popliteal muscles weak and wasted, but slight V P. Sole hypersensitive. No reaction to F or G in any muscles of leg. *Dec.*—Wound healed. *Feb.*, 1918.—OPERATION (H. S. S.). External popliteal found divided. Direct suture. Internal popliteal freed. *June.*—Weak power in flexors of toes.

Case 102.—*April*, 1917.—Perforating wound upper part of back of R thigh, another outer side of popliteal space. Total sciatic paralysis of leg. *July.*—Complete paralysis external and internal popliteal, with R D anæsthesia. V P in hamstrings. *Sept.*—Paralysis as before, but pressure over nerve below wound causes tingling of leg and foot. *Nov.*—OPERATION (W. M.). Almost total division at level of lower border of gluteus maximus, with bulb on upper end. Resection suture over gap of 1¼ in. *April*, 1918.—No recovery V P or sensation, but muscles react briskly to G. Referred tingling obtained on pressure of external popliteal over fibula. *June.*—Referred tingling over dorsum of foot.

SUMMARY.—(8 *months*) *Sensation returning over dorsum of foot, but no voluntary power.*

Case 103.—*July*, 1916.—Small perforating wound L buttock. Anæsthesia back of thigh. No loss of power in limb. *Aug.*—Operation for hæmorrhage. Buttock opened up widely. Gluteal artery tied with great difficulty. *Sept.*—Paralysis of internal popliteal, with R D. *Nov.*—OPERATION (H. S. S.). Almost total scarring of internal popliteal found, small branch to hamstrings alone remaining: this was dissected away. Scar excised, and nerve sutured directly. *Dec.*—Transferred. *Nov.*, 1917.—No recovery. Stopped treatment since Aug. No work. *June*, 1918.—Reports referred tingling on pressure on calf. At work, but having no treatment.

SUMMARY.—(7 *months*) *Nerve sensitive in calf.*

Case 104.—*April*, 1917.—Small wounds outer side both knees. Foot-drop R side. Partial paralysis. *May.*—Slight numbness only dorsum R foot. V P and F present in peronei. Absent in extensors, with R D. *June* 19.—Numbness slightly improves. V P and reactions unchanged. Thickening felt on external popliteal behind biceps tendon. *June* 30.—OPERATION (H. S. S.). Nerve exposed, at emergence from cover of biceps tendon. Damage partial. Nerve split longitudinally into posterior external part (conducting F to peronei) and anterior inferior part (not conducting) of which ⅞ in. was resected, with end-to-end suture. Fat sleeve. *Sept.*, 1917.—No V P in peronei. Nil to F, moderately brisk to G. Other muscles R D. *Jan.*, 1918.—Fair V P in peronei returned in last few weeks. Nil F. No V P anterior tibial.

Case 105.—*July*, 1917.—Perforated wound behind outer side of R knee. Sciatic paralysis. *Aug.*—Complete external, partial internal popliteal anæsthesia. No V P in either, but spontaneous, painful, cramp-like movements in flexors of toes. Internal popliteal conducts F, and its muscles react. None in external popliteal. *Sept.* 18.—Cramp-like pains, but no spontaneous movements. Complete sciatic anæsthesia. Slight power internal popliteal, none external. *Sept.* 21.—OPERATION (H. S. S.) Explored popliteal space. Internal popliteal slightly constricted by fibrous band. Conducted F, and abnormally irritable to mechanical stimuli. External popliteal marked bulbous thickening. No conduction. Excision suture. *May*, 1918.—Fair power calf muscles, no V P in extensors, which react briskly to G, not to F. Referred tingling on pressure over neck of fibula. *June.*—Pin returned in upper third. Brush in upper third external popliteal area. Sensation completely recovered in internal popliteal area. *Aug.*—Fair V P external popliteal group, but no further sensory recovery.

SUMMARY.—(8 *months*) *Recovery, motor and sensory, internal popliteal. Sensory only external popliteal.* (11) *Motor recovery external popliteal.*

Case 106.—*June*, 1916.—Wound lower third of L thigh. Foot-drop. *July.*—Complete paralysis internal and external popliteal, with R D and sensory loss. *Nov.*—OPERATION (H. S. S.). Sciatic found completely divided, with large bulbous end. Excision and suture over 3-in. gap. Fat sleeve. *April*, 1917.—Complete sensory loss in sciatic area. Trophic ulcer of great toe. *July.*—V P in gastrocnemii, tibialis posticus, and peronei. Some sensory recovery upper peronei area. Ulcer healed. *Sept.*—V P all calf muscles. Fair V P peronei and tibialis anticus. No further sensory recovery.

SUMMARY.—(8 *months*) *Power in muscles of calf and peronei.* (10) *Fair power in all muscles.* (12) *Almost complete motor, but no sensory recovery.*

Case 107.—*June*, 1917.—Wound R leg, outer side below knee. *July.*—Anæsthesia external popliteal. Slight V P external popliteal muscles. Fairly brisk reaction to G. *Aug.*—Power improving. *Jan.*, 1918.—Fair power all muscles. No sensory recovery. *April.*—Pin produces radiating tingling in upper half of affected area. Tingling also produced by pressure on nerve below scar. V P in extensor longus hallucis and tibialis anticus only. No response to F. *May.*—OPERATION (L. E. C. N.). Neurolysis. Perineural adhesions only. *June.*—Sensation recovering on dorsum of foot. Weak V P in all extensors. None in peronei.

SUMMARY.—(1 *month*) *Definite recovery in sensation and power.*

SCIATIC NERVE (CASES NOT OPERATED).

Case 108.—*April*, 1917.—Perforating wound back of R thigh. Internal popliteal paresis. Pain in sole, anæsthesia to pin. Wasting and weakness of calf. No power in tibialis anticus or flexors of toes. *July.*—Pain improved. Slight power in gastrocnemii. No power, and R D in other muscles of calf. *Jan.*, 1918.—Fair power in gastrocnemii. No change in sensation. Discharged.

SUMMARY.—*Recovery of power, not of sensation, 9 months after injury.*

Case 109.—*Sept.*, 1916.—Wound L thigh. Fractured femur. No nerve lesion noticed. *April*, 1917.—Complete paralysis of L sciatic, with R D and anæsthesia. Onset gradual for last two months. There have been several operations for sequestrotomy. *Aug.*—Transferred.

SUMMARY.—*Transferred without operation.*

Case 110.—*Jan.*, 1917.—Wound upper third L thigh. Fractured femur. *Sept.*—Anæsthesia complete sciatic area, slight V P peronei. None in other muscles. No reaction to F or G. Wasting of leg severe. Nutrition bad. *April*, 1918.—Fair power in all muscles of leg. Slight return of sensation on outer side. *May.*—Sensation dorsum of foot completely recovered. Still complete anæsthesia of sole. Good power extensor muscles. Very weak in flexor. *June.*—Sensation recovered in whole of external popliteal area. Fair power in all muscles of leg.

SUMMARY.—*Fair recovery of power in all muscles, and of sensation, except in sole of foot, 18 months after injury.*

Case 111.—*Feb.*, 1917.—Large wound inner side of L thigh, high up. *March.*—Secondary hæmorrhage. Ligature of branches of profunda. Foot-drop followed. *June.*—Wound healed. Paralysis tibialis anticus and extensor longus hallucis, with R D. V P peronei and extensor longus digitorum. External popliteal anæsthesia. *Aug.*—Slight V P in paralyzed muscles. Sensation recovering. *Oct.*—V P much improved. *Jan.*, 1918.—Fair power in all muscles, except tibialis anticus. Discharged P U.

SUMMARY.—*Fair recovery, except tibialis anticus, 11 months after injury.*

Case 112.—*July*, 1917.—Large wound inner aspect of thigh above knee. Very weak power all leg muscles. Anæsthesia small sciatic area. *Aug.*—Anæsthesia outer side of sole only. External popliteal recovering V P. Very slight V P internal popliteal group, with complete R D. *Oct.*—Fair power in external popliteal. Complete paralysis of internal popliteal, with painful anæsthesia of sole. Marked trophic changes in skin of foot. Transferred.

SUMMARY.—*External popliteal recovered 3 months after injury. Transferred without operation.*

Case 113.—*April*, 1916.—Wound R thigh. Fractured femur. *Oct.*—Weakness posterior tibial group, calf tender, mixed hyperæsthesia and anæsthesia of sole. Partial R D in calf muscles. *Jan.*, 1917.—Completely recovered.

SUMMARY.—*Complete recovery 9 months after injury.*

Case 114.—*Aug.*, 1916.—Large wound back of upper R thigh. Fractured femur. *Jan.*, 1917.—Paralysis of anterior tibial muscles, with R D. No sensory loss. Transferred.

SUMMARY.—*Transferred without operation.*

Case 115.—*April*, 1917.—Wound L buttock. *May.*—Large abscess in buttock opened. Foot-drop noticed few days later. *June.*—Incomplete internal popliteal paralysis, small area of anæsthesia. Loss of power in extensors of foot, which give R D. *Sept.*—Recovering power, R D still present in extensors. *Feb.*, 1918.—Complete recovery. V P and sensation.

SUMMARY.—*Complete recovery 9 months after injury.*

Case 116.—*July*, 1916.—Perforating wound L buttock. Sciatic paralysis. *Sept.*—Complete sciatic paralysis below knee, with R D, and anæsthesia. Refused operation. Discharged.

SUMMARY.—*Discharged without operation.*

Case 117.—*July*, 1916.—Small wound over head of L fibula. Foot-drop. *Aug.*—Numbness in external popliteal area. Muscles paralyzed, but reactions normal. *Sept.*—V P returning. *Dec.*—Complete recovery.

SUMMARY.—*Complete recovery 5 months after injury.*

Case 118.—*April*, 1916.—Wound L buttock. Foot-drop. *July.*—External popliteal paralysis, with R D. *Oct.*—No return of V P. Reaction of peronei to G brisk. *July*, 1917.—V P in peronei. Paralysis and R D of other muscles. Sensory loss limited to dorsum of foot. Transferred.

SUMMARY.—*Recovery of peronei only 3 months after injury.*

Case 119.—*Aug.*, 1917.—Perforating wound L leg, just below knee. Severe pain in sole. *Sept.*—Intense causalgia of sole, without sensory loss. *Oct.*—Greatly improved. Transferred.

SUMMARY.—*Much improved 2 months after injury.*

Case 120.—*June*, 1916.—Perforating wound back of R thigh just above knee. Foot-drop. *Aug.*—Paralysis external popliteal, with R D and anæsthesia. *Sept.*—Muscles recovering. *Nov.*—Fair V P. Transferred.

SUMMARY.—*Fair recovery 5 months after injury.*

Case 121.—*Dec.*, 1916.—Perforating wound back of upper L thigh. *Jan.*, 1917.—Weak V P all muscles except tibialis anticus, which shows R D. Small area of sensory loss in sole. Tenderness in course of nerves. *March.*—Transferred.

SUMMARY.—*Transferred without operation.*

Case 122.—*Sept.*, 1915.—Wound L thigh in lower third. Fractured femur. *Nov.*—Bone united. *Feb.*, 1916.—External popliteal paralysis, with R D and anæsthesia. *May.*—Slight V P. Sensation recovering. *July.*—Power improving. No sensory loss. *Aug.*—Complete recovery.

SUMMARY.—*Complete recovery* **11** *months after injury.*

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SUTURE OF THE MUSCULOSPIRAL NERVE: THREE CASES.

By Captain GWYNNE WILLIAMS, R.A.M.C. (T.), London.

The following cases show the completeness with which motor recovery takes place after suture of the musculospiral nerve, and accord with the general impression as to the results of suture of this particular nerve. They are brought forward because they show the rate of recovery of the nerve and—by the order in which recovery of the muscles takes place—emphasize the progressive down-growth of the axis-cylinder. They are also put forth as offering a hypothesis to explain the difference in the results of suture in the musculospiral as opposed to other nerves.

The technique of the operation has in every case been quite simple, the nerve ends being brought together without any tension by a single catgut suture through the substance of the nerve. The line of suture has been wrapped round with subcutaneous fat. Precautions were taken to prevent any tension on the union until a month had elapsed. In all cases the muscles paralyzed were relaxed by an extension splint. In *Cases* 1 and 3 the fingers were kept extended from the first; but in *Case* 2 this was not done until the radial extensors had recovered; this helped to prevent the stiffness of the metacarpophalangeal joints, which is liable to occur as a result of prolonged extension of the fingers even when massage and movements are used daily. In *Case* 1 no other treatment was carried out, but in *Cases* 2 and 3 massage and galvanism were employed.

Case 1.—J. M., age 15, came under my care at University College Hospital, on Oct. 2, 1916, having cut his right arm just above the elbow-joint a month before. The wound was not quite healed, and there was complete musculospiral paralysis. The muscles were relaxed by an extension splint, but no recovery having taken place by Dec. 24, 1916, the nerve was explored.

Operation.—The ends of the nerve were separated by about one inch; they were freshened, and sutured with catgut, the line of suture being wrapped in subcutaneous fat.

The radial extensors recovered by April 12, 1917. I did not see the patient again until May 14, when the extensors of the fingers had recovered. On June 10 the extensor longus pollicis showed definite voluntary movements. The after-treatment consisted entirely of relaxation, since the patient was unable to attend for massage and galvanism.

Case 2.—B. Gunshot wound, March 23, 1917, involving the right musculospiral in the middle of the upper arm. The wound took some time to heal.

Operation.—Sept. 3. The nerve was found to be completely interrupted; both ends were freshened, and sutured with catgut, the line of suture being wrapped in subcutaneous fat.

The patient was not seen by me for some time, but says that he noticed recovery of the wrist-drop at the end of Feb., 1918. I saw him on March 4, and the radial extensors had recovered. On May 7 I received a report from Dr. Murray Levick that there was voluntary movement in the extensor communis digitorum and the extensor ossis metacarpi pollicis, but not in the extensor longus pollicis. On June 25, the latter muscle showed definite voluntary movement, but was not very strong. The after-treatment consisted of relaxation, massage, and galvanism.

Case 3.—J. S. M. Gunshot wound, Nov. 5, 1916, involving the musculospiral and musculocutaneous nerves at the outlet of the axilla on the left side. No suppuration.

Operation.—Jan. 6, 1917. The musculospiral was found to be completely interrupted by scar tissue; this was excised and the nerve sutured with catgut, the suture line being covered by a sheath of subcutaneous fat. The musculocutaneous was fixed by scar tissue, from which it was released, and the nerve wrapped in fat.

Movement in the biceps was first noticed on Feb. 22, 1917. In July, movement was suspected in the extensors of the wrist, and by the middle of September the hand could be supported, the extensor carpi radialis longior acting well. Extension of the little finger was noticed by Dec. 15; by Christmas the middle and ring fingers had recovered, and the index began to move about Jan. 16, i.e., a year after the operation. At the end of February there was a faint sign of movement in the extensor longus pollicis.

These facts as to recovery have been sent me by the patient from Australia; I have not seen them myself. The treatment was relaxation, massage, and galvanism.

It will be seen that recovery took place most quickly in *Case* 1, where the lesion was most peripheral, and that it was slower when the lesion was higher up. Thus the distance

of the line of suture from the elbow-joint, which corresponds roughly with the entrance of the branches into the radial extensors, was in *Case* 1 one inch, in *Case* 2 three inches, and in *Case* 3 seven inches, while recovery was noticed in these muscles in three and a half, six, and eight months respectively.

The next group of muscles to show recovery is the extensor communis digitorum, which the posterior interosseous nerve supplies immediately it has passed through the supinator brevis ; the times of recovery in this muscle group being five, eight, and twelve months. The last muscle to recover in each case was the extensor longus pollicis, in six, ten, and fourteen months respectively ; the nerve to this muscle is a long branch which enters the muscle about 5 in. distal to the elbow-joint.

Circumstances have necessarily rendered any more exact investigation of these cases difficult ; but the facts that have been presented show that recovery in any muscle is proportional to the distance of the lesion from the entry of the nerve into the muscle, and that the rate of growth of the axis-cylinder is about one inch in a month.

These three are the only cases of suture of the musculospiral nerve which I have been able to follow up in any way, and at first I was surprised at the completeness of their recovery, since there was no difference in the technique of the operation which was in any way likely to account for their success. Secondary suture of a nerve has always been regarded as unsatisfactory, and it seemed extraordinary that three consecutive cases should succeed. Reports of cases from other sources soon showed that suture of the musculospiral nerve gave very satisfactory results, so there must be some reason why the musculospiral nerve differs from other trunks such as the median and ulnar, where the recovery is very seldom complete. The only difference in the after-treatment usually carried out was that in the case of the ulnar and median it was very difficult to relax the muscles of the hand satisfactorily ; I tried various devices, but without success.

I therefore conclude that it must be the composition of the nerve that made the difference. The musculospiral trunk is almost entirely motor, the sensory distribution being not only small in area, but the area is, relative to the median and ulnar, of slight importance, so that the sensory nerve fibres are probably very few.

Any given axis-cylinder starting out from the upper end of the divided musculospiral nerve is almost certain to find its way down a motor path ; whereas with a mixed nerve, such as the ulnar, if we presume that the motor and sensory fibres are equal in number, the chances of a motor or sensory fibre finding its proper destination are about 50 per cent. There is no evidence that a motor fibre can pick out a motor path, or a sensory fibre a sensory path, and it would be expected that each fibre would take the path that was nearest. The deduction from this would be that a purely motor nerve or a purely sensory nerve should recover almost completely after a satisfactory suture, and in a mixed nerve the recovery might reach completeness if the approximation of the sections of the nerve was topographically accurate ; but unless this rather improbable condition of affairs was brought about, the sensory and motor recovery would both be partial.

Further, it might be said that if the suture of a purely motor nerve fails on one occasion, there seems no reason why it should not be undertaken again, unless it can be shown that there is a time limit after which the axis-cylinders will not grow down the nerve peripheral to the section. The results in a mixed nerve might be improved if it were possible, by knowledge of the topographical arrangement of the various nerve bundles in a trunk, to approximate the ends more accurately : it is possible to do this roughly in the upper part of the sciatic, but it is doubtful if it could be done in the median or ulnar, displaced as they frequently are by dense scar tissue.

The proof of this hypothesis would require an extensive series of observations on the relative motor and sensory composition of nerve trunks and the results of suture. Light would be thrown on the question by cases of suture of the facial and hypoglossal nerves. If shown to be true, it would be an important factor in determining the prognosis of nerve injuries.

I have to thank Colonel Bruce Porter for permission to publish *Cases* 2 and 3, which came under my observation at the 3rd London General Hospital.

SOME NOTES ON OPERATIVE PROCEDURE IN NERVE INJURIES.

By ROBERT KENNEDY, Glasgow.

In operations for the restoration of damaged nerves there are many conditions which must be present before a successful result can be looked for. Where there is evidence of damage to a nerve trunk, and an open wound or a septic sinus exists, the first step is to get the wound or sinus healed by ordinary surgical treatment. After the part is healed completely, and a sufficient time has elapsed for the scar to be safely dealt with, the question of operation may be considered.

When the time for operation arrives, there are certain conditions which must be observed before a successful result may be prognosed. Thus, in the case of the nerve having been severed, it is necessary to find the two separate segments. These again must be healthy or undamaged by inflammatory processes, excepting in so far as the ends are affected by scar formation. The exposure of the nerve segments should be made above and below the seat of injury, in accordance with the anatomical indications. After the central and peripheral segments have been found, they should be traced downwards and upwards respectively towards the seat of injury. Any attempt to cut directly into the damaged part is apt to lead to a long and futile search for the nerve ends. Cutaneous scars over the seat of injury of the nerve should be removed if possible by joining the two incisions made above and below by an elliptical incision encircling the scar, so as to effect the removal of the cutaneous along with the underlying scar.

In the vast majority of cases both segments of the nerve trunks when exposed are found to have a greater diameter than the nerve when normal. Usually this need give no concern—the thickening is due to œdema of the nerve trunk, and does not appear to affect the result. Certain thickenings of the nerve are, however, of a different nature, and have a serious effect on the outlook. The nerve trunk may be found inflamed, appearing dusky-red with dilated vessels, and this condition is associated with pain of a very severe nature. In such cases the best treatment consists of incisions into the thickened and inflamed trunk, made in a longitudinal direction to avoid injury to the nerve fibres. Should the trunk have been extensively damaged, and be now found thickened with scar formation, the prospects of a satisfactory result are extremely bad. These cases, however, are very exceptional, and in the majority the two segments are all right except at the seat of section. As a rule there is practically no difference in the thickness of the central and peripheral trunks.

When the nerve ends have been dissected out, they may be found in various conditions. The severance may have been complete, with no reunion. Both ends may present bulbs, that on the central end being usually the larger. Both ends may be without bulbs, but terminate in tapering ends involved in scar. Sometimes the central end presents a bulb and the peripheral a tapering termination. Sometimes, again, a kind of reunion has been effected between the two ends; this may occur as a strand of much greater tenuity than the nerve, or it may present a swelling considerably thicker than the nerve. Sometimes two nerves in close approximation have been divided, and the ends have united in a cross—or more frequently one central end has become joined to the peripheral end of the other nerve, the two remaining ends being ununited. A nerve and tendon may have been simultaneously severed, and the central end of the nerve be found to have united firmly with the peripheral end of the tendon, or vice versa.

In order to test the conductivity of the nerve, an electrical interrupted current may now be applied to the exposed nerve trunk by a sterilizable electrode. The application should be made as soon as the nerve is exposed, before any manipulation of it has taken place, and may be repeated from time to time as different parts are brought into view. The presence of conductivity is shown by contraction of the muscles supplied by the nerve. When the entire distribution of the nerve trunk has been found to be affected before the operation, it is very seldom that the electrical stimuli produce any muscular contractions; but in certain cases where the trunk has only been partially damaged, or reunion has been partially effected, it may serve to show to what extent the nerve is conducting. The current, to begin with, should be the smallest necessary to evoke a contraction; and it will be found that the nerve trunk, when irritable, can be stimulated at different points in the circumference, with different contractions resulting, the fasciculi supplying different groups of muscles being thus capable of being separately stimulated by a current not strong enough to stimulate the entire trunk. Before being applied to the nerve, the electrode should be tested on an exposed muscle in the vicinity in order to see the amount of current passing.

Before dealing with the ends of the severed nerve, it is necessary to pay attention to the surroundings of the nerve trunk. If these consist of dense scar, the scar masses must be cut away so as to leave normal tissue for the sutured nerve to lie in. Any neglect of this will end in failure; and should it be impossible to leave the nerve in healthy surroundings, a bad prognosis should be given. The same applies in the case of a nerve damaged in a part which has dense surroundings naturally, being confined in a narrow space. The most frequently occurring example of this is the ulnar nerve, when damaged behind the elbow, where it is lodged behind the internal epicondyle in a sulcus having for its boundaries the internal epicondyle and the olecranon process of the ulna. In this case it is probably impossible to get a satisfactory result unless the nerve is dislodged entirely from its position behind the epicondyle and fixed in front of the epicondyle and under cover of the humeral origin of the flexor carpi ulnaris where it is not confined by bony surroundings. The reason is that the enlargement which forms at the seat of suture compresses itself against the rigid boundaries of the sulcus and thus prevents conductivity

Where the loss of conductivity has been due, not to section, but to compression by cicatricial tissue or otherwise, attention must be directed entirely to the surroundings of the nerve, and on dissecting out the compressed trunk and ascertaining that it is intact, it only remains to dissect the cicatricial tissue away: the removal must be thoroughly done, otherwise recurrence of the compression will probably take place. When this is not possible for any reason, the prognosis is not good. In some cases the compression has been so severe that the nerve on removal of the scar shows a constriction over the entire extent of the compression; at other times the compressing ring has been so narrow that a furrow surrounding the nerve is all that shows the site of the compression on removal of the cicatrix. Should the perineurium be intact, such compression furrows or constriction do not call for excision, for the nerve will recover quite well. The constriction is not really so deep as it appears, owing to the œdematous condition of the nerve trunk above and below, which has not been under compression.

The next step is to determine the possibility of getting the segments to meet. This should be done before the nerve ends are prepared for suture, as otherwise the manipulation necessary to make them meet might so damage the freshly prepared ends as to endanger the result. At times they meet quite easily, but in other cases it is quite impossible to get them to do so. If the nerve has simply been shot through with a bullet, there is no difficulty; the ends may have retracted some distance, but this can be overcome. In other cases, however, such as shell wounds where a large piece of the nerve has been shot away, or where a septic condition has resulted in the sloughing of a large piece of the nerve, it may be impossible to bring the ends together.

If the ends do not come into apposition easily, various procedures may be adopted. Care should be taken, first of all, to see that the segments of the nerve trunk are not caught in a cicatrix further up, or down; this is often the cause of the difficulty in

making the ends meet, and when this cicatrix is cut, contact is easily made. Should this not be the cause, then see if relaxation of the nerve can be obtained by a movement of the joints above and below the seat of nerve section. In the sciatic, coaptation may be effected quite easily with the knee flexed, when separation by a considerable distance would be the result in the extended position ; in such a case the nerve is sutured with the knee flexed, and the flexion position is maintained until the wound is healed, after which the limb is gradually extended and the nerve stretched without harm. This is also the case with the median and musculospiral in the arm by flexion of the elbow, and with the median and ulnar in the forearm by flexion of the wrist. Flexion or extension of the elbow has little effect on the ulnar in the arm. In the case of the median, ulnar, and musculospiral in the arm, adduction of the arm causes relaxation. This is not so noticeable in the musculospiral on the outer aspect of the arm, where the limb is adducted when the nerve is being exposed ; but in the case of the median, ulnar, musculocutaneous, and musculospiral in its upper part, the limb may be postured for the operation in a position of abduction, even to a right angle ; this should be remembered if any difficulty of approximation arises, as the operation can be finished with the limb adducted, and thereby great relaxation of the nerve trunks will be obtained. In all cases where the ends of a severed nerve are being approximated by means of flexion of a joint, it must be carefully kept in mind that no relaxation must be permitted until the wound is healed. The danger lies in an extension movement being inadvertently made by the assistant who is holding the limb in the flexed position ; and it is necessary to watch that this is not done, or the nerve ends may thereby be torn asunder. When the brachial plexus is being dealt with above the clavicle, relaxation of the nerve trunks is brought about by raising the shoulder and abducting the head on the side of operation ; this may enable a gap to be bridged and a suture to be tied ; the position must, of course, be maintained by an appropriate splint throughout the healing of the wound.

In the event of the necessary relaxation not being thus attained, stretching of the nerve trunk should be tried ; but this should not be done until it is ascertained that less forcible methods fail, as it is a good principle in all operations on the nerves to use as little force as possible, and to conduct every procedure with the utmost gentleness. But the ends must be induced to meet if possible.

In stretching the nerve trunk, the method of procedure is to grasp the nerve with a piece of gauze, and make steady traction, avoiding any sudden movement, and being most careful not to allow the grasp to slip along the nerve : this is harmful from the irritation which it causes by damaging the surface of the perineurium, with the further possibility of dense adhesions forming along the nerve trunk. If the traction is excessive, then rupture of the nerve fibres may occur, but it is astonishing how much traction can be borne without this accident. Any operator may satisfy himself on this point should he meet with a case where partial reunion has occurred in a motor or mixed nerve and some of the muscles have recovered a partial nerve-supply. Here the only satisfactory method of treatment is excision of the cicatricial segment and suture ; but in certain of these cases the reuniting segment which requires excision is so long that stretching may be necessary to effect apposition. In such conditions the application of the electrode to the distal segment will show at certain points responses in the muscles, and these can be re-examined after each stretch. It will then be found that the ordinary stretching necessary to effect considerable elongation does not rupture the fibres, as the muscles continue to give their responses. This is just what might be expected from what we know of the condition of nerve fibres in severed nerves. If a portion of a nerve trunk is excised and prepared for microscopical examination, longitudinal sections always show the fibres to follow an undulating or zig-zag course ; and if preparations are desired showing the nerve fibres running a straight course, it is necessary to put the portion of nerve on the stretch when it is fresh, and to keep it stretched while fixing. It is this undulating course of the fibres in a severed nerve which permits of so much stretching of the nerve trunk without rupture.

Stretching presents unusual difficulties in the case of the cords of the brachial plexus

above the clavicle. Many years ago, in dealing with cases of Duchenne's paralysis, which is due to rupture or cicatricial compression of the fifth and sixth cervical nerves at their junction in the plexus, I found this difficulty very great. These trunks are often fixed in a cicatrix over a considerable area, and it is necessary to work in a small space above the clavicle. Section of the clavicle would give freer access, but is a most undesirable complication of the operation. The nerve trunk, once exposed, has to be fixed while being cleared of cicatrix, and I found that when I fixed the scar with forceps while the nerve was being put on the stretch for clearing adhesions, the cicatrix became torn and finally ruptured, after which the completion of the operation was difficult. I therefore devised a nerve stretcher which I have since found of great help in suitable cases—viz., those where the ends of the nerve are united in cicatrix which, while reuniting the ends, permits no efficient conductivity, and which must therefore be excised. The instrument, as shown in *Fig.* 288, consists of a piece of thin steel cut in the shape of a cross, each arm terminating in two prongs with bulbous ends. The breadths of the arms at their terminations measure respectively $\frac{1}{4}$ in., $\frac{3}{8}$ in., $\frac{1}{2}$ in., and $\frac{5}{8}$ in. The prongs are intended to be placed astride the cicatrix, and on rotating the instrument, as shown in *Fig.* 289, the nerve is efficiently put on the stretch with no damage to the nerve itself, only the cicatrix being pressed upon, and this is to be excised before suture, at the points A and B. On stretching the nerve, the adhesions are drawn taut, and fly asunder on being touched with the knife. At the same time the distal end of the nerve is drawn up into approximation with the central. The different spacing between the prongs adapts the instrument to different lengths of cicatrix, and the bulbous ends prevent the instrument from slipping once it has grasped the cicatrix.

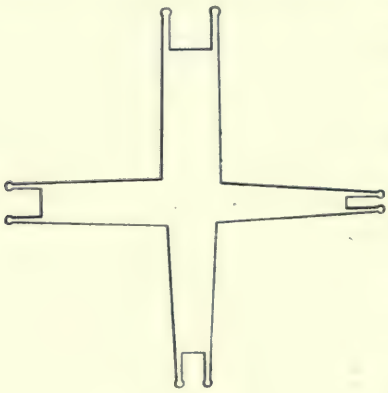


FIG. 288.

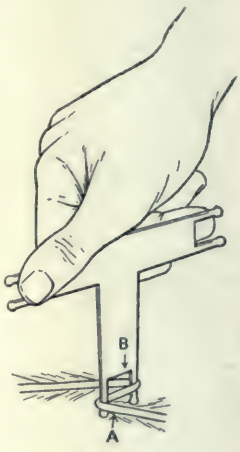


FIG. 289.

Another procedure which may be adopted to effect approximation of the nerve ends is frequently applicable to the ulnar when wounded in the arm or forearm. This depends on the fact that the ulnar is very greatly relaxed when displaced from the sulcus to a position in front of the internal epicondyle of the humerus, and wide gaps between the nerve ends can thus be overcome. It is done by making an incision over the ulna at the elbow and dissecting an anterior flap forwards. The ulnar is then made to follow a course between the muscles arising from the internal epicondyle. This is sometimes done by dissecting out the distal end of the ulnar, when the lesion is in the arm, and passing it through between the muscles into the arm; in other cases by incising the humeral origin of the flexor carpi ulnaris, placing the nerve in position, and then suturing the muscle over the nerve.

Should the nerve ends only meet with difficulty, showing much strain, it is better to fix them not quite in contact, rather than that the ends should be overstrained. In such cases good results are obtainable in spite of the fact that the approximation has not been absolute.

But there are cases in which no possibility of any reunion can be entertained, so great is the distance between the ends. Here the question of implantation or of grafting will arise, both of them procedures fraught with difficulties. It has been proved that one nerve can take the place of another, and enable function to be carried on; but the result is never up to the normal standard and is inferior to that of reunion. It has been proved also

that a portion of nerve when excised and implanted under the skin in another part of the body is not absorbed, but remains as a piece of nerve. Two nerves like the median and ulnar, one only of which has suffered a considerable loss, may be taken as an example. The sound nerve may be incised transversely, to the extent of about a third of its thickness, at two points separated widely enough to permit the central and peripheral ends of the damaged nerve to be stitched in without tension. It is possible that the fasciculi cut may be mainly sensory fibres, but that should not matter, as they are merely wanted to connect the two ends of the damaged nerve, and ought to serve this purpose equally well whether sensory or motor. It would be different in the case of an anastomosis, say, between the damaged facial nerve and the sound spinal accessory nerve, for there the central end of the facial is not available, and therefore the entire spinal accessory must be cut across to give a share of all the motor fibres. The same would apply to the principle of anastomosis performed in any nerve. The objection to the method is the cutting across of sound nerve fibres; but this is necessary if the method is to have a chance. The plan advocated by some of making a longitudinal incision in the sound nerve is, of course, quite useless, as it sections very few—a quite negligible number—of sound nerve fibres, and consequently there is nothing available for the new supply.

In the event of complete section of the nerve, the next step in the operation is to 'freshen the ends' preparatory to suture. This term, which is frequently used, is apt to give rise to a misconception as to what is to be done. The word 'freshening' would indicate the removal of the surfaces in a wound so as to prepare the way for the union of fresh surfaces; but in the case of the ends of a nerve which has been divided and has not reunited, or which has reunited by a cicatrix which does not conduct nerve impulses, the freshening required is the removal of all new formation, whether neuroblastic or fibroblastic in origin. In all cases it is most essential to see the normal appearance of the fasciculi in the nerve section, and slice after slice must, if necessary, be cut from the nerve end until this is attained, not only in the central but also in the peripheral end. The appearance is usually typical—the fasciculi projecting out from the perineurium in the form of small cylindrical processes (*Fig.* 290). When this is seen, all is satisfactory as far as the nerve end is concerned. Sometimes, however, the appearance is slightly different, and the fasciculi appear larger, do not project beyond the surface, and have a glairy look; this is due to œdema, and is also quite satisfactory. Sometimes one is tempted to stop the slicing process before these appearances are seen, because of the difficulty in getting the two ends to meet; but the temptation must be resisted, for if nerve ends which have been inadequately prepared are united by suture, the result cannot be promising.



FIG. 290.

Bulbous ends are formed partly of cicatricial tissue and partly of young nerve fibres which have developed outside and beyond the old neurilemma sheaths, and are therefore disposed tortuously. It is not safe to reunite a nerve trunk by means of the bulbs; some result might be obtained in this way, but it is apt to be imperfect; the connective-tissue element in the bulb may contract and interfere with the conductivity. It is therefore right to remove the bulbs entirely.

Where a severed nerve is joined by means of a cicatrical segment blocking the passage of impulses completely or incompletely, it must be cut out, the exact point of excision above and below being determined by the slicing process until the fasciculi are exposed.

Having prepared the ends, the next question is how best to suture them, and what material to use. Since it is necessary to leave some foreign matter at the seat of reunion in the form of a suture, the important points are to use the material which will cause the least irritation, and to use the smallest possible quantity of it. The idea of enclosing the ends in a membrane to prevent interference with the process of regeneration from the surrounding fibroblasts is not new, having been employed by Vanlair many years ago; more recently Cargile membrane has been largely used for this purpose. The great objection, however, to such procedures is that the foreign material left at the seat

of suture is considerable, and requires either to be absorbed or encapsuled ; both of these processes are accompanied by considerable reaction, and this may result in new formation of connective tissue which may prevent the desired result by its contraction.

Numerous or too thick sutures are objectionable for the same reason, and are quite unnecessary. The nerve ends can be quite sufficiently coapted by a single fine suture, passed once through each end, and tied not too tightly, but sufficiently to hold the two surfaces in apposition (*Fig.* 291). The other method is that of suturing the perineurium only, several sutures being placed round the nerve so as to coapt the two ends exactly without passing through the portion of the trunk transmitting the nerve fibres. The objections to the perineural suture are that more material is left at the seat of suture, and that although the periphery is closely coapted, the two surfaces bounded by it are not so well held together as with a through-and-through stitch, and may be separated by blood-clot as shown in *Fig.* 292.



FIG. 291.

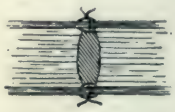
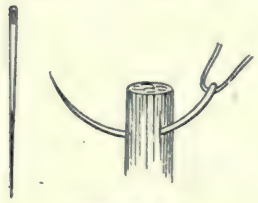


FIG. 292.

The amount of damage to the nerve fibres caused by a single through-and-through stitch is very trivial, and can be reduced to a minimum by the use of the special needle represented in *Figs.* 293, 294. This needle is curved, and to the extent of one third of its length from the point is flattened from side to side with a cutting edge on concavity and on convexity. About one third of its length from the point the needle gradually increases in breadth so as to permit the eye to be made in the same plane as the two cutting edges. Many needles have the eye passing in the opposite direction to the cutting edges, and this makes a great difference in the amount of damage which the thread inflicts on the nerve during the passage of the threaded eye. The nerve is transfixed as shown in *Fig.* 294. The flat needle cannot wound many fibres in its passage, and the loop of suture is so placed, owing to the direction of the eye, that it easily takes the slit made by the needle.



FIGS. 293, 294.

The thread employed in the suture may be absorbable, or one which requires to be encapsuled. If the former, then the finest catgut should be chosen, and prepared by some method which renders it sterile and absorbable in fourteen days. I have always employed, except in experimental work on small animals, chromicized catgut, specially prepared for this purpose by my staff.* In the case of extremely fine nerves in experimental work on monkeys, where the finest catgut would be relatively too thick for suture of the nerve without causing too much damage, I have used horsehair, and found it very successful. The nerves reunited functionally, and at the physiological examination the horsehair was found encapsuled at the seat of suture. It is a perfectly safe suture, and could well be used instead of catgut in any case.

There now only remain a few general considerations. Nerve regeneration, whatever be its nature, finds without any doubt the greatest bar to its successful accomplishment in the development of the fibroblasts into fibrous tissue. This has not only an antagonistic effect on the process of regeneration, but a destroying effect after that process is accom-

* The raw catgut is loosely wound on reels made of glass rods bent into rectangles, one piece only being put on each reel so as to allow the different liquids free access to the gut. On these reels it is soaked in ether for twenty-four hours to remove fat, and then dried in air. It is now soaked in 0·1 per cent aqueous solution of chromic acid for three days, and then washed in running water for two or three hours to remove all unfixed chromic acid. It is next boiled in alcohol in an open glass tube for one hour—not with any intention of sterilizing, but so as to dislodge all the air-bubbles from the interior of the gut thread—and then allowed to cool in the alcohol. It is these air-bubbles which make catgut so difficult to sterilize, as they prevent the antiseptic from getting access to the organisms in the portion of the gut lodging the air-bubble. The gut is finally soaked in 20 per cent carbolic glycerin for a few days, and preserved in the same fluid till required for use. Before use, the antiseptic is removed by soaking the gut in alcohol.

plished. In operative work, therefore, everything which tends to produce scar formation militates against success. Aseptic technique of a high standard is essential if good results are to be expected. It is no proof to the contrary if a case of nerve suture has become septic and yet a good result has followed: it will certainly be a very exceptional occurrence. Therefore the greatest care to prevent the entrance of organisms into the wound is a rule the importance of which cannot be overestimated, in order to leave as little sterilization work to be done by the tissues as possible, and thus require the minimum of reaction in the wound. It is true that many cases of subcutaneous rupture of nerves are met with in which no recovery of function takes place, although no bacteria have been at work at the seat of rupture; but in these cases the failure to unite functionally is due to the same cause—namely, the intensity of the reaction, leading to the formation of connective tissue which contracts and prevents conductivity in any nerve fibres which may have regenerated. This reaction is not due to micro-organisms, but to the trauma which caused the rupture and the processes which follow thereon.

For the same reason it is essential that all manipulations of the nerve throughout the operation should be of the gentlest. The knives should be as sharp as possible, all nerve slicing should be done with a fresh knife which has not been used since it was sharpened, and the slicing should be performed with a gentle sawing movement so that the fibres sustain as little damage as possible. The less force required to effect all the procedures, the more likely is there to be a good result. This is the chief reason why it is desirable to use a tourniquet, applied after the limb has been emptied of blood as completely as possible, so that the procedure shall be bloodless. The bleeding is often considerable in these cases, particularly if there has been much scar formation, and the constant swabbing which is required to keep the parts clear, and the application of hæmostatic forceps and ligatures, must considerably irritate the parts in which the newly-sutured nerve is to lie. If the limb is properly emptied of blood, the whole procedure may be carried out in a much shorter time; and there is no need for swabbing, and consequently much less trauma. Before the suture is completed, if there is any chance of damage having been done to a vessel of any size, the tourniquet may be removed, the vessels ligated if necessary, and then the nerve operation completed and the wound closed; but in the absence of this exceptional circumstance, the best way is to close the wound, apply the dressing firmly, and then remove the tourniquet. Any blood that oozes from the capillaries escapes into the dressings and does no harm, and it is a very rare circumstance for there to appear more than sufficient to stain the innermost dressing.

SHORT NOTES OF RARE OR OBSCURE CASES.

A CASE OF GUNSHOT INJURY OF MECKEL'S DIVERTICULUM.

By Major GORDON TAYLOR, R.A.M.C. (T.C.)

Pte. W. G. E., was admitted into a casualty clearing station in the spring of 1918 with a shell wound of the right buttock, but with obvious signs and symptoms of a penetrating injury of the abdomen; he had been hit six hours before.

The missile was found to have entered the right buttock, and to have opened the right side of the perineal portion of the rectum about two and a half inches from the anus; it had entered the right infero-lateral and extra-peritoneal wall of the bladder, and emerged from the peritoneal surface of this viscus at the junction of the superior surface and the base. The track between the rectum and the buttock was laid widely open, and the sphincter divided. The wound of the peritoneal surface of the bladder was excised, and the edges were sutured with catgut; the cavum Retzii was drained with a piece of rubber sheeting.



Fig. 295.

There were sixteen perforations of the ileum, and several holes in the mesentery; two of the wounds in the bowel were along the mesenteric attachment. There were also two small wounds in a Meckel's diverticulum which was present. It was deemed necessary to resect the damaged portion of the ileum, and the resection was extended downwards so as to include the portion of bowel to which the diverticulum was attached; three-and-a-half feet of small intestine were removed, and an end-to-end junction was made. The Meckel was rather under one inch in length, and somewhat tri-lobed at the end; the missile had perforated it near the distal end (*Fig.* 295). In spite of the severity of his injuries, the patient made a good recovery, and was evacuated to the base eleven days after operation; five weeks later a satisfactory account of his progress was obtained.

The injury cannot be a very common one, and the case therefore seems worthy of record.

I am indebted to my friend and colleague, Captain H. T. Andrew, R.A.M.C., for the sketch which accompanies this note, and to Colonel L'Estrange, R.A.M.C., for permission to publish the notes of the case.

A CASE OF CONGENITAL DEFECT OF THE THORAX, WITH SPRENGEL'S DEFORMITY.

By Captain HAROLD BURROWS, R.A.M.C. (T.F.)

The patient, age 20, is a private in the machine-gun corps. In peace time he is a grocer's assistant. All his life he has noticed a bulging of the left chest whenever he coughed,



Fig. 296.—Patient when at ease. Outlines on chest demarcate boundaries of defect in chest wall as elicited by palpation and verified by radiogram.

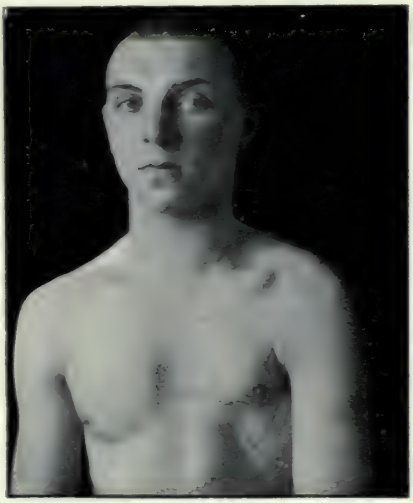


Fig. 297.—Shows patient while making a forced expiratory effort.

but he has not experienced any particular inconvenience from this. He was able to undergo his course of training as a soldier, and made no complaint on account of his deformity, though he says he has always found it difficult to carry his pack.

On examination of his chest, it was found that the left anterior chest wall is defective, considerable sections of the second, third, and fourth costal cartilages and ribs being absent (*Figs.* 296, 297). The remaining ribs are normal in number, position, and shape. The pectoralis major on the affected side is ill-developed; otherwise no defect of muscle or nerve is to be observed. The left nipple is smaller than the right, and is situated at a higher level. A hernia of the lung is visible when the patient coughs.

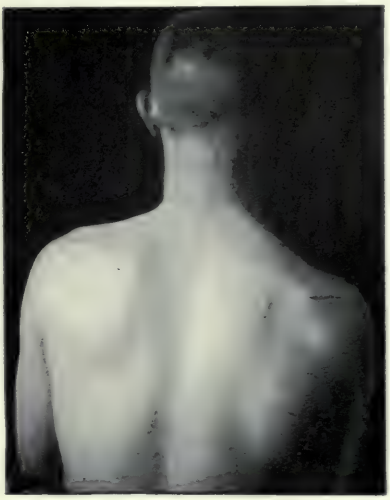


Fig. 298.—Back view of patient.

On viewing the patient from behind, the left shoulder is seen to be hunched up, while the left scapula is slightly smaller than the right, nearer to the vertebræ, and at a higher level (*Fig.* 298). The scapular muscles, however, appear to be well developed, though the posterior superior angle of the scapula is more clearly noticeable on the left side than on the right. There is a lateral curvature of the spine, with the maximum curve in the dorsal region, the convexity being directed to the right.

The left chest is retracted to a remarkable degree, as shown by the accompanying cyrtometer tracings (*Figs.* 299, 300, 301).

My colleague, Lieutenant S. Owen, informs me that there is no dextrocardia or other visceral abnormality to be found, nor are there any congenital defects other than those already mentioned

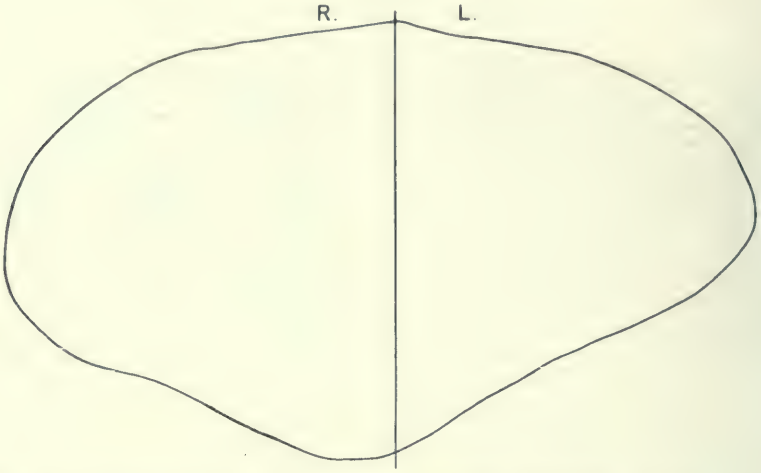


FIG. 299.—Cyrtometer tracing at level of first interspace. Circumferential measurement: R = 20 in. L = 18¼ in.

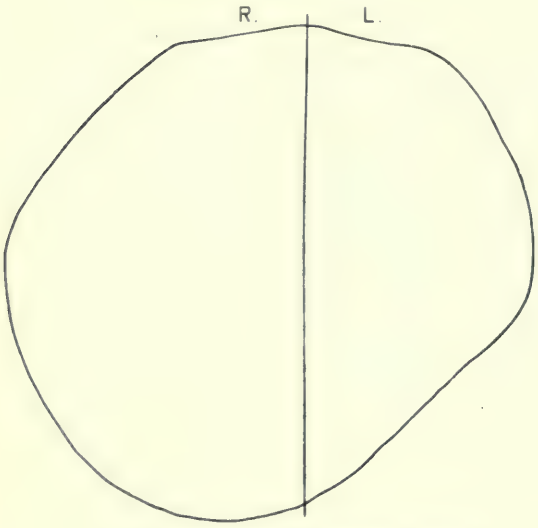


FIG. 300.—Tracing at level of fourth rib cartilage. R = 18 in. L = 14¾ in.

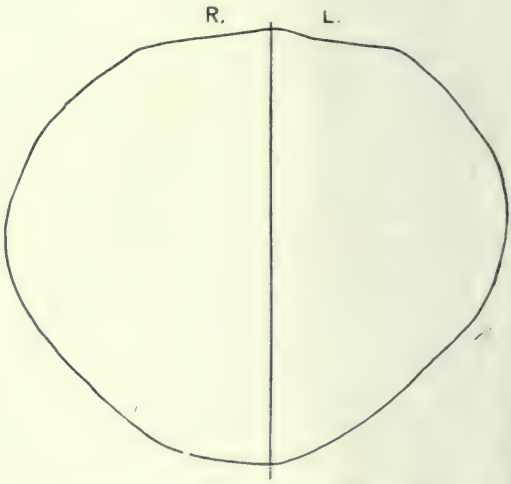


FIG. 301.—Tracing at level of tip of eighth cartilage. R = 15⅞ in. L = 11½ in.

The case is remarkable on account of its rarity, and also because the patient suffered so little inconvenience from his abnormalities.

I am indebted to Dr. F. Brigham, of Harvard University, for the photographs.

A CASE OF TORSION OF THE APPENDIX.

By JOHN E. PAYNE, Torquay.

There appears to be no record of this condition in the many works on the appendix; the following case may therefore be of interest.

Mrs. Z., a nullipara, age 37, had always suffered from constipation, the bowels sometimes not acting for seven days.

Ten years ago she had a sudden attack of abdominal pain and faintness which lasted for about six hours. There was no vomiting, and the pain gradually passed off. She was seen by a doctor, who diagnosed appendicular colic. Following that attack, the patient suffered from indigestion for several months, and since then has frequently had attacks of pain and soreness in the right iliac fossa on the second day of the menstrual periods. Two years ago there was another attack of pain lasting for thirty-six hours, associated with vomiting but not in relation to menstruation. This was diagnosed as a bilious attack. For the last month the indigestion has again been bad, with some abdominal pain, sickness, and a sense of fullness in the epigastrium.



Fig. 302.

On Monday, March 13, 1916, while travelling in a train, she was seized with sudden pain in the epigastrium after lunch. She vomited several times, but the pain continued and was of a colicky nature. At midnight the pain suddenly shifted to the right iliac fossa and became continuous.

The following day a doctor was called in; he ordered enemata, and three were given, with very copious results. On the 15th I saw the patient and operated the same evening.

On opening the abdomen through the right rectus incision, the appendix was found pointing downwards and slightly outwards in the right iliac fossa. It was quite free except for a slight recent adhesion from the extreme tip to the iliac fossa. On examination it was found to be twisted, and it took three complete turns to unravel it (*Fig.* 302). The appendix distal to the narrowing caused by the twisting was gangrenous, and the meso-appendix dark and swollen. The appendix was removed, and the abdomen drained through the original incision. The temperature and pulse became normal on the third day, and the patient made an uneventful recovery.

Remarks.—The appendix was $2\frac{3}{4}$ in. long, and contained fæcal material. It seems most probable that the previous attacks were due to a 'constipated appendix,' and that the torsion resulted from irregular peristaltic movements on the part of the appendix itself.

REVIEWS AND NOTICES OF BOOKS.

War Surgery of the Abdomen. By CUTHBERT WALLACE, C.M.G., F.R.C.S. Eng., M.B., B.S. Lond. Surgeon, St. Thomas's Hospital; Lecturer on Surgery in the Medical School; Consulting Surgeon, British Armies in France. Pp. 152; 26 illustrations. 1918. London: J. & A. Churchill. 10s. 6d. net.

No chapter of war surgery has been more dramatic than that dealing with abdominal wounds; the complete reversal of the practice of previous campaigns, the equipment of units for the performance of operations calling for the highest surgical skill within the battle zone, and the saving of nearly 50 per cent of those so wounded, were all accomplished within a year of the commencement of the war. This, perhaps one of the most difficult problems of the many that presented themselves to the surgeon, was one of the first to be settled. Before even the pathological processes underlying the evolution of an ordinary wound of the soft parts were understood, or fractures received more than casual attention, results were being attained in the treatment of penetrating wounds of the abdomen that have been but little improved since.

This rapid success must be attributed to the high state of evolution of abdominal surgery in the years immediately preceding the war, to the facilities for rapid transport by motor ambulance, and to the stationary warfare that became established after the first few months.

Wallace's book is chiefly based on cases operated on during the period July, 1915, to December, 1916; it embraces the work of many surgeons carried out at different hospitals on a wide sector of the front, and includes both quiet periods and times of heavy fighting. The many statistical tables built up from a large number of cases under such varying conditions form a valuable historical record, and afford a standard by which to judge the results of future work.

The operative mortality (all cases) is remarkably uniform throughout successive periods from July, 1915, to September, 1917, varying from 53·9 per cent to 51·3 per cent. It is interesting to observe, however, that whilst only 60 per cent of cases (310 out of 511) were operated on in the first six months, 76 per cent (640 out of 889) were so treated in the last nine months; this, together with the general speeding up of evacuation, which has resulted in more cases reaching the surgeon alive, means a very real improvement in results which the tables hardly bring out.

The rapid evacuation of these cases from the firing line, early operation, and retention in the unit in which they are operated on for some days after operation, are the three essentials for success. They are purely administrative problems, and any or all of them may be rendered impossible by the exigencies of the military situation. Speaking broadly, the arrangements of our French and Belgian Allies have been much the same as our own in dealing with these cases. More and more the attempt has been made to bring the surgeon to the wounded rather than carry the wounded to the surgeon. Perhaps this has been overdone; certainly, with the onset of more open warfare and the increased use of long-range artillery, there has been a reaction since 1916. The author is opposed on the whole to the advanced operating centre as the most suitable unit with dealing with these cases, especially during periods of heavy fighting, and prefers direct evacuation to a casualty clearing station in spite of the longer journey entailed: the smaller unit is liable to be swamped, because cases accumulate, and thus defeat the attempt to secure early operation. Certainly, with the diversion of heavy and lightly wounded cases to different casualty clearing stations and the pushing up of clearing stations nearer to the front line than was at one time the case, the advanced operating centre has to a large extent outlived its usefulness; nevertheless it played an important part in the evolution of abdominal war surgery.

From a clinical point of view these cases present many difficult problems even to the surgeon skilled in abdominal work in civil life. Wounds of the hollow viscera, wounds of the solid organs, penetrating wounds without visceral injury, and parietal wounds, may present a similarity of symptoms that makes an exact diagnosis at times almost a matter of guess-work. Under these circumstances an exploratory incision is frequently the wisest and safest course to take, and one rarely has cause to regret it. Hæmorrhage is the chief cause of the high mortality, and its persistence demands that intervention be carried out as early as possible. Pre-operative measures to combat shock are of the greatest importance, and only experience can enable a surgeon to select the proper moment to operate on a patient who is reacting to this treatment; in the same manner, when casualties are heavy, the greatest skill and experience are necessary to select those cases most likely to benefit by operative interference.

The author is to be congratulated on having produced a book, not only of interest from the point of view of what has been achieved, but also of considerable assistance to those who are at present engaged on the problems with which it deals.

Blood Transfusion, Hæmorrhage, and the Anæmias. By B. M. Bernheim, M.D., Instructor in Surgery, the Johns Hospital University. 8vo, illustrated. 1917. Philadelphia and London: J. B. Lippincott Co. 6s. net.

This book records a great deal that is of extreme importance to the physician as well as the surgeon, but it is unfortunate that owing to the author having had to depart for the Johns Hopkins Base Hospital Unit he was deprived of opportunity for its final inspection and revision. We feel certain that further deliberation would have led to the deletion of some of his suggestions.

The author discusses in detail the phenomenon of bleeding, and deals with many of the methods useful in differential diagnosis between hæmorrhage and shock. He is of opinion that transfusion is far from a serious undertaking, and that perhaps it is wiser to err by giving a transfusion when recovery might have occurred without this procedure, than run the risk of the patient passing into a state from which recovery is very doubtful. We have no hesitation in saying that anyone who has carried out a large number of transfusions will agree with Bernheim on this point.

The author suggests that transfusion is indicated in seven conditions: (1) actual hæmorrhage; (2) in connection with surgical operations; (3) for the relief of hæmorrhagic conditions; (4) blood disease; (5) infections; (6) poisons; (7) debilitated conditions.

He alludes to the dangers of transfusion, and points out how difficult it is to estimate the mortality following transfusion; we feel that this is of little importance unless the details of the methods adopted are recorded along with the reason for giving the transfusion. Several deaths referred to, are recorded by surgeons, and were due to unsuitable donors having been selected; that is to say, donors whose bloods belonged to different groups from that of the patients; this led to hæmolysis and agglutination. Six fatalities are alleged to have been due to causes other than hæmolysis: four to acute dilatation of the heart, and two to questionable anaphylaxis. With all deference, we express doubt as to these causes in the six cases. The symptoms of anaphylaxis and of dilatation of the heart simulate very closely those produced by agglutination of red corpuscles upon injecting unsuitable blood.

The importance of the suitability of the blood is emphasized by Bernheim in the following passage: "Thus the absolute necessity for preliminary tests must be apparent to all. When blood transfusion first came into vogue it was the common thing to poke fun at hæmolytic tests; many men had done numerous transfusions without tests and without the sign of hæmolysis or other trouble, so that the feeling arose that its occurrence was a remote possibility and therefore one to be ignored. But it was not long before cases of hæmolysis began to make their appearance, and with the growing popularity of transfusion they became more and more common, until a number of fatalities occurred, and a distinct change of sentiment concerning the importance of the complication was noted."

With this we agree, and think that if Bernheim had revised the book he would have deleted the latter part of the following passage: "In others, 50 c.c. a day for ten days may be sufficient, or 100 c.c. every other day, the idea being to use blood as a stimulant or perhaps even for its nutritional value, instead of giving it in bulk as is now customary. A husband, brother, or sister could give up these insignificant amounts of blood daily, or every two or three days, without inconvenience or harm, and it may even be proved that hæmolytic and agglutination tests will prove superfluous, since the amounts given would be so small as to be incapable of causing serious trouble."

The author refers to one death due to sudden agglutination in a case which, as far as the operator knew, was being transfused with the blood of the correct group, but subsequent observation showed that agglutination occurred when the bloods of the donor and patient mixed. Although we have never seen death result from this cause, we know of a case in which transfusion had to be stopped for a similar reason. The donor—who was believed to belong to *Group* 4, and who had given his blood with benefit to a patient suffering from pernicious anæmia, whose blood also was of *Group* 4—was used three months later as a donor to a *Group* 4 patient. Symptoms developed after a small quantity of blood had been injected, which led to the transfusion being stopped, and on re-examining the donor's blood it was found that he belonged to *Group* 3. Whether under any circumstances an individual can change from one group to another is a matter of interest, but at present evidence seems to point against it.

The importance of the donor and the patient being of the same group having been insisted upon, it seems rather a pity that Bernheim has relegated to the appendix methods of determining to which group an individual belongs, and the methods of deciding the compatibility of two bloods.

It is difficult to agree with the statement that "by many men it is considered quite unnecessary to carry out the group method of testing, a more direct means of attaining the same end being that of testing all prospective donors directly against the recipient until a suitable donor is secured," except when the medical man is but rarely called upon to carry out a transfusion. By classifying the prospective donors a list may be prepared, and one of a suitable group may be procured with minimum delay. Chance should be excluded whenever possible, and it is always within the limits of possibility that half a dozen or more donors would have to be brought to the patient, in order to select one belonging to the same blood group.

Bernheim refers to the danger to the donors, and states: "I have never lost a donor, nor have I heard of a person losing his life by giving his blood in a transfusion." This we can believe most readily. In the majority of cases, donors assert that they feel better after giving 700 c.c. of blood, and on the seventy-five occasions upon which we have observed the transfusion of blood,

we have never seen an untoward symptom. Bernheim is averse to giving any drug to the donor; we have reason to believe that a cup of strong coffee is of advantage. The author is not in favour of using the same donor time after time. Some have done so a dozen times or more, in a case of pernicious anæmia, with the idea that, by bleeding, a hormone might be formed which would stimulate the blood-forming tissues.

The methods of transfusion are given in considerable detail, and the advantage and disadvantage of each method carefully criticized. This part of the book will prove invaluable to those who are novices at transfusion, and if it had been in existence years ago it would have saved many practitioners much time and trouble. Lindeman's method is given in detail, but the citrated methods find favour in the eyes of the author; and no doubt, when blood is given simply to replace that which has been lost, the citrated method is as convenient and as satisfactory as any other.

In the chapter dealing with transfusion for pernicious anæmia, the author is disconcerting by confusing the argument for and against multiple transfusions with the question of splenectomy. We gather from the chapter that in no case which has come under his observation have transfusions been persisted in to the extent which experience has shown us is necessary. We have had under observation a case in which fifty transfusions have been carried out in two years, in order to maintain the patient's red cells above two and a half million per cubic millimetre. Bernheim concludes that in hæmorrhagic diseases, and in leukæmia, transfusion is of comparatively little value; but in these cases, too, perseverance is conspicuous by its absence.

The book is well illustrated, and the diction clear, although the author is too lavish with epithets. To-day few medical men can afford to remain ignorant of the facts recorded in it.

The Action of Muscles, including Muscle Rest and Muscle Re-education. By W. Colin Mackenzie, M.D., F.R.C.S., etc. 8vo. Pp. 267 + xvi. Illustrations 99. 1918. London: H. K. Lewis & Co. Ltd. 12s. 6d. net.

This book on the action of muscles is evidently the result of much original investigation. Dr. Colin Mackenzie is a devout follower of the teachings of Hugh Owen Thomas, and shows a keen appreciation of the work of John Hunter, Charles Bell, Duchenne, Haller, and Cowper, who all devoted much time to the study of motion.

A plea is made for wider recognition of certain principles in the treatment of muscle injuries and paralysis. The importance of physiological rest is emphasized, and simple methods of its application for each form of nerve lesion are illustrated. Re-education of muscle function follows the lines found effective over a long experience of successful treatment of infantile paralysis. The position of the different joints from which re-education should be commenced is clearly defined. This allows early volitional control to be established without the risk of overstrain.

The chapters dealing with the specialized action of muscles and their opponents explain, on a rational basis, many of the deformities now common in military surgery. The work of the modern physiologist and anatomist on the action of muscles is presented throughout in a form which makes it readily available to the clinician.

This book would be welcome at any time, but is especially so just now, when restoration of function in limbs is such a huge problem for the Empire. It should be widely read.

Laboratory Methods of the United States Army. *Medical War Manual No.* 6. Compiled by the Division of Infectious Diseases and Laboratories, Office of the Surgeon-General, War Department, Washington, D.C. 1918. Philadelphia and New York: Lea & Febiger.

This little book will be useful chiefly to research students and workers in hygiene laboratories. The sections dealing with the chemical investigations of urine, blood, water, and milk give well-selected methods, which are clearly described. The same can be said of some of the special bacteriological methods, e.g., the determination of types of pneumococcus, though the differentiation of the coli-typhoid group of organisms and the estimation of agglutination units could be stated more fully and more clearly.

The general rules obtaining in a laboratory, and the recipes for stains, solutions, and bacteriological media, etc., are sufficient, concisely set out, and should be valuable to the laboratory attendant. In a subsequent edition these could be amplified with advantage by the addition of some of the other useful media, e.g., Drigalski nutrose agar, whey agar, etc.

The section on clinical pathology is quite insufficient, and will be of no practical help to the medical officer engaged in the routine laboratory work of a field or general hospital.

The qualitative examination of urine includes no simple tests for recognizing the presence of blood; no reference is made to renal casts and their varieties; the detection of bilharzia, not infrequently present in troops who have served in Egypt, is not considered; the account of the varieties of crystals found in urine is very meagre.

In the few lines dealing with the examination of the blood there is no mention of the routine estimation of hæmoglobin percentage and colour index by means of a hæmoglobinometer. The

paragraph headed 'Differential Count' deals only with the preparation of blood films; the varieties of leucocytes to be differentiated are not even mentioned.

No mention is made of the varieties of malarial parasites commonly met with in routine work.

In the examination of fæces the differentiation of amœbæ and the presence and significance of cysts are not considered.

Examinations of the throat and mouth are restricted to diphtheria; no reference is made to Vincent's *B. fusiformis*, spirochætes, oidium, streptococci, etc.

On page 164, 'Simple Diagnostic Table for Gram-negative Bacilli' contains two serious errors. *B. coli communis* does *not* liquefy gelatin, and *B. paratyphosus* forms acid and gas with dulcite. Two paratyphoid bacilli, *B. lactis aerogenes*, and Morgan's bacillus are omitted from the table.

This booklet is disappointing. It has apparently been devised by an expert chemist, and to the chemical research worker it may possibly be a handy guide, though as a rule he will be supplied already with the text-books on his subject. For the laboratory attendant there are many and better-equipped manuals. To the clinical pathologist the book has no value. The table of contents is not a satisfactory substitute for a good index.

Generally, it would seem that an attempt has been made to cut a uniform for the use of several very different individuals, and the result is an unfortunate misfit.

Modern Urology: in Original Contributions by American Authors. Edited by Hugh Cabot, M.D., F.A.C.S., Boston, Massachusetts. Vol. I, pp. 744, 368 engravings and 7 plates; Vol. II, pp. 708, 264 engravings and 10 plates. Philadelphia and New York: Lea & Febiger. $14 net.

Modern urology in a "correlated set of monographs" by twenty-nine American contributors, each writing with the authority of a specialist, given 1452 pages in which to state their views untrammelled by the exactions of the systematic text-book, promises a feast of knowledge in this branch of surgery which should attract even the jaded surgical appetite of 1918. Let us see what the twenty-nine surgeons make of their opportunities.

Volume I opens with an historical sketch of genito-urinary surgery in America, by F.S. Watson, in which are brief notes of some of the more prominent men in the field of American urology, including one of Watson himself from the pen of Keyes junior. They are a distinguished company, among whom not the least striking is Bigelow. Here also is related the progress of urinary surgery in America; and surgical instruments and devices introduced by American surgeons are described. Then follows a careful and very concise account of the cystoscope and its use, by Leo Buerger: one of the best articles in the book.

Bransford Lewis has a chapter on methods of diagnosis, in which it is interesting to note a plaint as to the many failures in diagnosis that he sees, a note that might well find echo in this country. With this article (for it is incomplete as it stands and is none too full) should be read that of Dodd on *x*-ray diagnosis, and one by Geraghty in Volume II.

Geraghty's article on tests of the renal function is, as we would expect, clearly written and authoritative. The study of these tests has progressed rapidly in surgical work, and the subject possesses a voluminous literature. Geraghty's article helps to brush aside much that is superfluous and unnecessary in this difficult subject. The author rightly devotes a large part of his article to the phenolsulphonephthalein test which he and Rowntree introduced, and which is now accepted generally as the most reliable and easily applied of all the tests. No article has appeared in English medical literature on this subject, and Geraghty's synopsis will be welcome.

Corbus, writing on syphilis of the genito-urinary organs and on genital ulcers, suffers from the disability of having to deal with only a small section of an important general disease. Apart from this, the chapter is an excellent review of the subject, and there is a fairly complete bibliography. Strangely, he omits to mention congenital syphilis affecting the kidney, which has been described in this country and elsewhere.

A complete and instructive account of the diseases of the female urethra is written by Osgood.

Keyes junior deals with stricture of the male urethra in thirty-two pages. He looks upon the intensity of the gonorrhœal urethritis, not its chronicity, as the cause of the stricture. His statement that "gonorrhœal stricture is but a cicatrization of the pathological process that causes chronic anterior urethritis" is somewhat nebulous, but when he comes to treatment it is evident that his views in regard to the prevention of stricture by the intelligent treatment of chronic urethritis of the infiltrating type are on sound and generally accepted lines.

This author's views in regard to operation for stricture differ from those held in this country. Operation is reserved for cases where dilatation has failed. So far, so good; but note the nature of the operation. "For strictures of the pendulous and scrotal urethra, internal urethrotomy upon the roof of the canal. For stricture of the bulbous urethra, external urethrotomy." The reason for this selection of the operation according to the position of the stricture is not stated. The lines on resection of the urethra at the end of the article are disappointingly short and uninstructive.

The article on tuberculosis of the genital tract by Barney is excellent in its breadth of

view and evidence of wide reading, and in its detail. The paragraphs on prognosis are full of interest, and obviously based on careful work and wide experience.

Prostatic obstructions is the subject of an elaborate article by Pilcher. Obstruction from causes other than gross enlargement of the prostate receives but scant notice, and a more detailed account would have enhanced the value of the article. The author rightly insists upon the importance of thorough preparation before operation. He prefers prostatectomy in two stages in practically every case of glandular hyperplasia of the prostate. The three reasons he gives are entirely unconvincing. A small percentage of cases are selected for the two-stage operation by all surgeons experienced in urinary work. To subject every patient to the anxiety and discomfort of two operations, and to prolong the period of surgical convalescence by a week or ten days, appears to be an unnecessary infliction and not justified by results. The most striking feature of this article, next to the absence of any reference to the English literature on the subject of the operation, is the complete suppression of statistics giving results of the operation. The discussion of after-results, measured by work published by other surgeons, is also disappointing. Impotence appears to be confused with sterility, for it is attributed to "injury to, or removal of, the ejaculatory ducts."

Young's contribution is a very careful article on cancer of the prostate. The symptoms are considered in much detail, and this part of the article is specially valuable. The operative treatment, including the author's radical operation, is fully described, and the use of radium shortly considered. Five out of ten cases submitted to the author's radical operation were probably cured, but as these represent the whole of the operations performed in about fourteen years, the cases suitable for this operation are obviously very few.

Instructive articles by Kretschmer, Lower, Hagner, and Caulk do not call for detailed comment.

Cabot has two important articles on stone in the bladder and stone in the kidney and ureter. His discussion of the etiology of stone is the least attractive part of these articles. It is lacking in clearness, and there is no mention of the cement substance which is generally regarded as the most important factor. The operations for stone in the bladder are very fully and ably discussed. Cabot gives, unintentionally we believe, the impression that less credit is due to Bigelow than we in this country are accustomed to give him, and he further omits to mention that the battle for litholapaxy was fought by the surgeons of the Indian Medical Service. No mention is made of litholopaxy in children, and the author does not appear to be familiar with Keegan's work. The discussion of results of bladder-stone operations is incomplete without statistics, and none are given.

In discussing the methods of closing the kidney wound after nephrolithotomy, the author looks upon the use of mattress sutures as 'wholly objectionable,' and has seen necrosis requiring nephrectomy follow their use. This statement is too sweeping. Kidney surgeons of large experience constantly employ mattress sutures without such untoward results.

Tumours of the bladder are ably discussed by Geraghty. He points out that the nature of the tumour cannot be decided in all cases by histological examination of the base. On the other hand, he rightly insists that the information derived from the examination of small portions of a bladder tumour removed by the operating cystoscope is not always conclusive.

Bentley Squire's article on anomalies of the kidney, hydronephrosis, movable kidney, and injuries to the kidney, repays perusal; but something more might have been made of the subject of hydronephrosis, and the selection of cases for operation in movable kidney might with advantage be more fully considered.

Infection of the kidney is discussed in detail by Keyes junior, and tuberculosis of the kidney is dealt with by O'Neil in an article that gives a very clear picture of the disease and an excellent summary of the treatment and the results to be expected therefrom.

The second volume closes with a carefully written account of tumours of the kidney by Binney.

The two volumes are profusely illustrated in black and white and in colour, the former being more successful than the latter. There are many fine illustrative drawings excellently reproduced, and the *x*-ray photographs are of exceptional quality. Photography has been used to illustrate some diseases and operations, and one feels a protest might be made against this form of illustration, which, except for imparting a sense of realism and providing a quite unnecessary certificate of good faith, teaches, in most cases, nothing. Most of the illustrations are original, and those borrowed are acknowledged. Young's article, however, is marred by the reproduction of three original illustrations from an English text-book without acknowledgement.

Looking back over these volumes as a whole, there is a sense of incompleteness that arises from the somewhat unsystematic nature of the book; there is the want of correlation and the redundancy that result from a number of independent authorities working in watertight compartments; there are the excursions into ancient history in some articles, the omission of which might well be excused by the title of the book; there is the robust pan-Americanism of the writing that we confess just now and then jars slightly on one outside the circle of American urologists; but taking it all in all, brilliant articles and mediocre, concise and well-weighed writing with diffuse and slovenly, the publication is indeed a notable one, and creditable to the remarkable body of men who have produced it, and to the Editor, of ancient surgical lineage, who contributed to its articles and moulded and guided its development and birth.

ROBERT LISTON.

1794–1847.

Robert Liston was born on October 28, 1794, in the manse at Ecclesmachan in Linlithgowshire, the eldest son of Henry Liston, whose father and grandfather had also been ministers of the church in Scotland. His father was a writer on music, the inventor of the euharmonic organ, designed to give the diatonic scales in perfect tune, and an improver of the plough; he also published selections from Horace and the sixth book of Cæsar, for the use of schools. A brother—David—became Professor of Oriental Languages at Edinburgh.

Robert Liston was educated by his father, and having entered the University of Edinburgh in 1808, was awarded the prize for Latin prose composition at the end of his second session. In 1810 he began to attend the lectures of Dr. John Barclay, a well-known extra-academical lecturer on anatomy and physiology, who soon afterwards appointed him as his assistant and prosector, a post he retained until 1815. From 1814 to 1816 he acted as 'surgeon's clerk,' or house surgeon, at the Royal Infirmary, first to George Bell and afterwards to Dr. Gillespie.

In 1816 he visited London, and put himself under Sir William and Mr. Thomas Blizard at the London Hospital, and attended the lectures of Mr. Abernethy at St. Bartholomew's Hospital. At the end of the year he was admitted a member of the Royal College of Surgeons in London. He then returned to Edinburgh, and taught anatomy in conjunction with James Syme, his junior, who afterwards became his successful rival From 1818 to 1828 he worked hard in Edinburgh, and built up for himself a good reputation as a teacher and as a surgeon. Cases which had been considered incurable by the surgeons of the Royal Infirmary fell into his hands on their discharge, and were operated upon by him with success. He was even said to have inveigled patients out of the Infirmary for that purpose, but this charge he stoutly denied. His methods and success caused feelings to run high amongst the surgeons in Edinburgh; no one would assist at his operations, and the managers of the Infirmary actually proposed to him that he should refuse assistance to any person who had been a patient in that institution, and that he should abstain from visiting or attending the wards. He declined to give such an undertaking: and he was thereupon formally expelled, and never entered the gates of the institution for a period of five years. In 1827 he was suddenly elected one of the surgeons by the exercise of private influence, and in the following year he was made the operating surgeon. In 1833 James Syme, his younger rival and former colleague, with whom he had quarrelled, was chosen Professor of Clinical Surgery, and in the following year Liston was invited to become one of the surgeons to the newly-formed hospital attached to the London University, now University College Hospital. He came to London, and was appointed Professor of Clinical Surgery in the University of London.

For some time his professional prospects seemed so doubtful that he thought of migrating to the United States; but practice came, and on the death of Sir Anthony Carlisle in 1840 he was nominated a member of the Council of the College of Surgeons, and in 1846 was elected a member of the Court of Examiners. In 1841 he became a Fellow of the Royal Society. His surgical practice soon became extensive; but in the spring of 1847 he began to suffer from signs of some obscure illness, which ended on December 7 in the rupture of a thoracic aneurysm. He died in Clifford

Street, in the house afterwards occupied by Sir William Bowman, and was buried in Highgate Cemetery.

Liston's claim to remembrance lies in the boldness of his operations, assisted by his sound knowledge of surgical anatomy, which enabled him to operate successfully in cases from which other surgeons shrank. Living at a time immediately antecedent to the introduction of anæsthetics, he attained a dexterity in the use of cutting instruments which had probably never been equalled, and is unlikely to be surpassed. When chloroform was unknown, speed was of the utmost importance in the performance of a surgical operation, as it saved pain to the patient and anxiety to the surgeon. "Who that once saw Liston perform a capital operation could ever forget it?" asks one of his pupils. "The manner in which he handled the knife had in it something remarkable. It at once put the spectators at their ease, and convinced them that the instrument would not go anywhere or do anything but what it ought. He possessed a confidence and self-possession that no untoward event ever disturbed; a readiness in suddenly applying expedients that seemed to the inexperienced the result of forethought; and a power in his muscular arms and bony hands that enabled him to twist, depress, or elevate parts with an ease that appeared almost magical. As a lithotomist he excelled, and his flap amputations were performed with such rapidity that the sound of sawing seemed to succeed immediately the first flash of the knife. With him the length of operations was estimated by seconds instead of minutes, and the student who unwarily turned his head to address his neighbour, on looking round often discovered that what he had struggled so much to witness had already been performed. Yet in all this there was no real hurry; it was the result of a skilful combination of movements performed with precision and exactitude." These very qualities occasionally led him to disaster, as when he opened an aneurysm instead of an abscess with one bold sweep of his knife, or undertook the removal of inoperable tumours, disasters which his numerous enemies were only too glad to magnify.

Liston, with the help of William Cadge, afterwards of Norwich, performed the first operation under ether in Europe, on December 21, 1846. The patient was a man suffering from a septic arthritis of the knee. The thigh was amputated in twenty-five seconds, and the patient left University College Hospital cured on February 11, 1847.

Liston lived at a time when professional rivalry only too often degenerated into personal abuse, and hatred reached bounds of which the present generation has no conception. Rough and ready, his manner towards his inferiors and those who differed from him was often most offensive, and his language was so coarse as to be often brutal. Many stories are told of his rudeness, and of the retorts to which he thereby laid himself open. After an altercation with Syme, whose head he had publicly compared to the skull of an ape, his coachman asked, "Where to, sir?" as he got into his carriage. "To the devil," said Liston. "Does His Majesty want an operation?" quietly asked the man. Yet, withal, Liston was generous-hearted, and some at least of his quarrels were made up before he died. A man of great stature and strength, he rode often to hounds, and had a yacht on the lower reaches of the Thames, for he had wished to follow the sea before his attention was turned to surgery.

Liston had no claim to the title of a scientific surgeon; he was not a good speaker, nor was he very clear as a writer. He published two books which ran through more than one edition, *Elements of Surgery*, in 1831, and *Practical Surgery*, in 1837. His efforts were directed towards the simplification of methods. In the treatment of wounds he was opposed to the method of occlusion then in common use, and advocated delayed suture of amputation flaps and a water dressing. This practice continued long after his death, and was at length replaced by the principles enunciated by Lister. In like manner, he taught that a fractured thigh should be kept straight instead of with the limb bent, as was then usual. "Some prejudice," he says, "has



ROBERT LISTON.

From a chalk drawing now in the possession of Mr. Raymond Johnson, F.R.C.S. Eng., to whom it was given by Sir John Eric Erichsen.

always existed against the straight position of fractures, as it is thought that certain muscles must act so as to pull the ends asunder. In trying to humour one set of muscles, however, others are necessarily put upon the stretch and excited, whilst in the extended position it is found that all become quiet very shortly, and the ends of the bones fall into their natural position." To secure this end he evolved the splint still known by his name, to replace the cumbersome apparatus devised by Desault, Boyer Stanley, and Hagedorn. The splint still retains vestigia of its original use in the digitate lower end and the two holes in the upper extremity, for Liston obtained extension and counter-extension by the splint itself, and made no use of the weight of the patient, as was done afterwards. Liston also appears to have invented the bone-cutting forceps, with one surface flat and the other bevelled, which is still in common use.

The illustration is made from a chalk drawing in the possession of Mr. Raymond Johnson, F.R.C.S. Eng., to whom it was given by the late Sir John Eric Erichsen, Bart.

ON CANCER OF THE TONGUE: THE BRADSHAW LECTURE, 1918.*

By D'ARCY POWER, London.

Mr. President and Gentlemen,

It was, I think, a wise latitude on the part of Mrs. Bradshaw when she founded this lecture in the year 1882 in memory of her husband—Dr. William Wood Bradshaw, M.A. Oxon., D.C.L.—to lay down no limitations as to its scope. It was to be a lecture on Surgery, and it is thus left to each lecturer to choose his own subject.

When the President invited me to undertake this honourable duty, I hesitated to accept, because in the hurry of these latter days it is difficult to find time for the original research which can alone render it of permanent value. I reflected, however, that you had recently nominated me to serve as one of your representatives on the Executive Committee of the Imperial Cancer Research Fund, and this gave me an opportunity of dealing with a topic which embraces the clinical and scientific sides of that dreadful disease. I have therefore chosen for your consideration this afternoon the subject of 'Cancer of the Tongue,' one of the most distressing forms of cancer which afflicts the human race. I have done so the more willingly because it brings into close relationship the historical, clinical, and scientific sides of inquiry, and it seems to me that these three lines must be closely followed if any satisfactory conclusion is to be arrived at.

PECULIARITIES OF CANCER OF THE TONGUE.

Cancer of the tongue, as is well known, presents several peculiarities which make it worthy of careful consideration. In the first place, it is almost entirely a human disease, and this is remarkable, because the tongues of many animals are more liable to injury than is the human tongue. Secondly, cancer of the tongue is always primary, and is always of one type—a squamous-celled carcinoma. This is noteworthy, because the tongue of all animals contains many varieties of epithelium, any one of which might be expected to undergo malignant change as easily as the squamous epithelium. Cancer of the tongue is unknown in children; it is rare in young people; becomes frequent between the ages of forty and sixty; and, until lately, it has diminished in frequency in extreme old age. It is common in men; rare in women. Moreover, it does not run the same course in men as in women: in men, it generally ends in death within eighteen months of the onset; in women, it appears more often to run an erratic course. I shall presently mention the cases of women in whom recurrence took place with such rapidity, after a complete operation by a competent surgeon, that nothing more could be done three weeks later, and of others whose sufferings were mercifully ended by death after eighty-four months and one hundred and eight months respectively of constant pain. Lastly, the inherited predisposition to cancer which is thought to be a feature in some forms of carcinoma seems to be nearly absent in cancer of the tongue. Each of these peculiarities is deserving of more careful consideration than it has hitherto received, for each must be due to some discoverable cause. I propose therefore to offer a few suggestions which may be interesting to you and serviceable to those who choose to work further upon the subject.

* Delivered at the Royal College of Surgeons of England, November 14, 1918.

I. HISTORICAL.

I will deal first with the historical side, and in doing so I find a virgin page in the history of medicine. No one, so far, has made any attempt to write about the literary history of surgical disease, though such a study would be of great interest and value. Such a history would be easier to write than that of medical complaints, because visible pathological conditions are more readily observed than those which are hidden.

The classical writers were well acquainted with cancer of the breast, of the uterus, of the penis, and of other parts of the body. From Hippocrates downwards, they give directions for the treatment of these diseases either by medical or surgical means, and state when they may and when they may not be removed. Cancer of the tongue, at any rate in its later stages, is no more difficult to recognize than epithelioma of the penis; yet Dr. E. T. Withington, who is making a special study of the old Greek writers for a new edition of Liddell and Scott's *Lexicon*, tells me that he has noticed a curious absence of any direct mention of cancer of the tongue in the Greek medical writers. The twelfth section of the second book of the *Prorrheticon** contains an injunction to examine the teeth in cases of chronic ulcer on the side of the tongue. The passage immediately preceding it treats of the deep and superficial *καρκίνοι* occurring in elderly persons, and it looks therefore as if the writer thought that chronic ulcers of the tongue might sometimes be of this nature, but did not like to say so definitely.

Galen (b. A.D. 131) describes functional disorders of the tongue, but says that he purposely omits organic diseases because he is considering them elsewhere. This treatise, unfortunately, has not come down to us.†

Oribasius (A.D. 326–403) in his *Synopsis* has a chapter on 'Malignant Ulcers,' where he mentions cancer and malignant ulcers of the pudenda, testes, and breasts. He also has a chapter on cancer of the vulva, which he says is incurable, and gives some methods of relieving the pain, but gives no hint of any similar affection of the tongue. It is probable, therefore, that he was unfamiliar with cancer of the tongue, and had never seen a case.‡

In like manner Rufus, commenting on Oribasius (45, ii), gives a detailed account of the different forms of carcinomata and their usual localities, but omits all mention of the tongue.

Rhazes (A.D. 850–923 ?), says nothing about 'apostema durum' when enumerating the different forms of 'apostema' which occur in the tongue.

Avicenna (A.D. 980–1037), in his *Canon of Medicine*, devotes a long chapter to the tongue. He may have obtained his account of the 'apostema durum' and cancer of the tongue from the lost treatise of Galen. At any rate he mentions cancer as distinct from 'apostema durum.' It is possible, therefore, that he had seen or heard of a case, but he gives no detailed description of one.§

Arnold of Villanova (A.D. 1238–1314), who was an epitome of the medical knowledge of the school of Salerno, wrote a chapter on 'Ulcers and Pustules of the Tongue,' but without mentioning any condition which can at all be described as cancer.

Bernard Gordon (fl. 1285), his contemporary, devoted a long chapter to 'Diseases of the Tongue' in his *Lily of Medicine*. He there speaks of 'ulcera maligna,' but states that

* HIPPOCRATES, *Opera*, Genevæ, 1657, p. 96 E.

† The tongue, he says, is liable to "inflammationes, tumores duri, tumores molles, erysipelata, suppurationes, de his vero, utpote quae tum visu tum tactu discerni possunt, nihil aliud in hisce commentariis dicemus, quippe eas duntaxat affectas partes hoc in libro prosequi proposuimus." (*Galeni Opera*, Basil, 1549, vol. iv; *De Locis Affectis*, Liber iv, cap. ii, p. 88 C.

‡ The passages occur in the *Synopseos*. Under 'De Ulceribus Malignis,' he mentions "medicamenta ad carcinode, malignaque ulcera, ad pudendorum, testium et mammarum inflammationes." (Liber vii, cap. xi.) A little farther on is the chapter 'De Cancro Vulvae,' of which he says, "Hic morbus curationem non recipit."

§ AVICENNA, *Canon*, Liber iii, fen. vi, cap. 14, 'De Apostematibus Linguae.' "Quandoque accidunt linguae apostemata calida, et apostemata phlegmatica, et apostemata ventosa, et apostemata dura, et cancer. Et signa omnium illorum manifesta erunt cum redierint ad illud quod dictum est in signis apostematum."

they are seen chiefly in children, and are easily cured by simple remedies. In all probability, therefore, they were aphthous ulcers.

William de Salicet (fl. 1245), Lanfrank (d. 1306), Henri de Mondeville (1260–1320), Jan Yperman (1275–1330), Gui de Chauliac (d. 1368), and John Arderne (1307–1390), all writers of the great surgical text-books of the thirteenth and fourteenth centuries, neither mention cancer of the tongue, nor do they describe any condition which in the least resembles it.

John of Vigo (1460–1517), with his keen surgical instinct, and Fernelius (1497–1558), who wrote on *Universal Medicine and Pathology*, would certainly have alluded to the condition had it been of frequent occurrence in their practice. Both are silent.

Riverius (1589–1655) devoted the fifth book of his *Praxis Medica* entirely to diseases of the tongue. The first edition was published in 1640, and he there says expressly, " Tumours of the tongue do not for the most part endanger life unless they grow so large as to cause suffocation, or come from a certain malignant or melancholic humour, when a cancerous swelling may be produced which is known by its hardness, blueness, and pricking pain."* It would seem from this passage that Riverius had actually seen cancer of the tongue, but it is noteworthy that he gives no details of any case in the volume which he published containing accounts of the many patients who had been under his care during his long and busy life.

The first definite notice of cancer of the tongue which I have been able to find is in English. It occurs in *The Chirurgicall Lectures of Tumours and Ulcers*, which were given by Dr. Alexander Read to our predecessors, the United Company of Barber Surgeons, in their Hall in Monkwell Street, on Tuesdays in 1635. Dr. Read says,† " It falleth out sometimes that sores in this member (the tongue) prove maligne and very fretting, as it happened to the late Lord Mayor of London, Ralph Freeman. Hee lacked neither Physitians nor Physicke, yet old age, weaknesse and the malignitie of the sore hindered the procuring of his health, which his Physitians and Chirurgeans aimed at and wished for. The ulcer was so corrosive that it fretted asunder the veines and arteries of the tongue on that side which it possessed and caused a great flux of blood which exceedingly weakned him, for that present causing a strong syncope, so that afterward nature could not re-collect her selfe. When such griefes befall great personages their case is worse than that of the poorest in the like infirmities, because Physitians and Chirurgians are not permitted to use the like libertie in the application of medicaments to the one as to the other. If the like case fall out hereafter at any time, I advise you to use medicaments borrowed of the vegetables so that you contemne not the minerals. What hurt I pray you can come from the use of Merc. Dulcis and Merc. præcipitat. with gold ? None I assure you ; for these medicaments are familiar to nature and are true balsams for maligne sores.

" But you may aske what was the reason these medicaments were not used ? I answer, because there was no mention made of these medicaments at the first, and it was too late to minister them at the last, nature being surprised : for this only would have made the medicaments odious, and the Physitian (who should have advised this course) obnoxious to calumnie and reproach."

Ralph Freeman died on March 16, 1633–4, during his year of office as Lord Mayor of London, evidently from secondary hæmorrhage due to cancer of the tongue. Dr. Read wished to administer mercury, but was overruled. It is possible, therefore, that he thought an antisyphilitic course might have been useful ; on the other hand, mercurius dulcis, which was the precursor of calomel, was just coming into vogue, and was being employed in every form of inflammation by those advanced physicians who had adopted

* " Tumores linguae ut plurimum vitae periculum non afferunt nisi in tantam molem excreverint ut inde suffocatio metuenda sit, aut ex humore quodam maligno atque atrabiliario ortum duxerint unde cancrosus tumor generari potest quod duritie, lividitate, ac dolore pungitivo internoscitur."

† " *The Chirurgicall Lectures of Tumors and Ulcers*, delivered on Tusedayes appointed for these exercises and keeping of their Courts in the Chirurgeans Hall these three yeeres last past viz. 1632, 1633 and 1634. Lond. 4to. 1635." Treat. 2, lect. 26, p. 313.

the new chemical pharmacy then replacing the treatment by herbs which had been in use from time immemorial.

It is interesting that this first record of a case of cancer of the tongue which I have been able to discover should have been presented just two hundred and eighty-four years ago to an audience similar to that which I am now addressing—the Master, Wardens, and Members of the United Company of Barbers and Surgeons: the only difference being that attendance on Dr. Read's lecture was compulsory, the attendance here to-day is voluntary. At that time it was enacted that "every man of the Company useing the mystery and facultye of surgery—be he freman, fforeyn or alian straunger—shall come unto the lecture, being by the Beadle warned thereto. And for not keepinge their houre both in the forenoone and also in the afternoone and being a ffreman shall forfayt and paye at every tyme iiiid."

From the middle of the seventeenth century onwards, cancer of the tongue was a well-recognized surgical disease in England, for Wiseman and other writers on surgery make frequent mention of it, and were devising methods for its cure.

It was, however, still rare in Germany, for Paul de Sorbait published a case in 1672. "We saw," he says, "an ulcer [of the tongue] degenerating into cancer in the case of the noble Baron Vertemali, which caused such a hæmorrhage from destruction of the sublingual arteries and veins that the patient was suffocated. He recognized with great penitence that the cause of this cancer was a divine punishment because he had often abused the clergy." *

Bonetus (1620–1689), writing on the tongue and its diseases thirteen years later, seems to have been unable to find another case—unless, indeed, he wished to point a moral—for he quotes the same case with some elaboration of details. "There was lately," he says, "a certain Baron who had a very poisonous tongue. He not only directed his jibes against all and sundry, but kept his most venomous shafts for the clergy and those who devoted themselves to God's service. He was caught at last in the very act when he was pealing this cursed bell, by a holy brother of good repute, who said to him, 'Your foul tongue has overlong deserved that punishment from an offended God which it will shortly receive.' The Baron went off undismayed, but a few days afterwards a small swelling began to grow on the side of his tongue. Little by little it increased in size until it became an inoperable cancer, and at length, the tongue having become incurved, twisted, and drawn back to the fauces, miserably afflicted, but penitent and confessed, he was summoned before the Great Judge who calls his servants to a most strict account." †

I think from the historical side it is fair to assume that cancer of the tongue has always existed; that during the classical and mediæval periods it was so rare as hardly to merit attention by the ordinary writers on surgery; in the seventeenth century it became common; and, as I shall show presently, its frequency is still increasing.

During the sixteenth century, therefore, something occurred to increase the frequency of cancer of the tongue; and three causes at once suggest themselves, for they were new factors, and greatly influenced the social life of the time—syphilis, tobacco, and the consumption of alcohol in the form of spirits. Of syphilis I shall speak in greater detail presently.

* *Universa Medicina*, Tract. I, cap. 34. "Vidimus in Illustrissimo Barone de Vertemali, utpote qui, in cancrum degenerans, corrosis sublingualibus venis et arteriis, hæmorrhagiam tantam excitavit, ut ea suffocatus fuerit Aeger. Causam hujus cancri, summa ductus pœnitentia, agnovit ipse divinam, eo quod Religiosis graviter et frequenter detraxisset."

† "Nuper quidam Baro in more habuit venenatissima Linguae jacula, non tantum in quemlibet sed maxime in Deo devotos religiosos frequentissime jaculari; in flagranti a pio honestæque vitae religioso deprehensus fuit, cum infernale hoc pulsaret tintinnabulum; ad quem religiosus ait, quam maledicta tua lingua jamdudum meruit poenam ex justa Dei vindicta intra breve tempus experietur. Relicto et minime commoto Barone, elapsis paucis diebus Tumor exiguus ad Linguae latera pullulare coepit, qui paulatim crescens carcinomatis inexpugnabilis naturam manifestavit, a quo tandem incurvata, convulsa et retracta ad fauces lingua, miserrime delictum, poenitenter confessus ad strictissimum Judicem suorum famulorum vindicem acerrimum, commigravit. (*Medicina Septentriolanus Collatitia*, 1685, vol. i, p. 302. The case is headed 'Tumor Linguae Miraculosus.')

Tobacco, as is well known, was brought from Cuba by the Spaniards in 1497, and under the name of Petum was introduced into Europe on account of its medicinal properties. Inhalation of the smoke was also learnt from the Indians, but it was not until 1586 that Ralph Lane brought the implements and materials for smoking into England, although a few persons had acquired the habit as early as 1573. It quickly took root amongst the Elizabethan courtiers, the pipes being short and made at first of silver and afterwards of clay, as is known from the pipes and pipe-cases belonging to Sir Walter Raleigh, which are still preserved in the Wallace Collection at Hertford House.

The poor at this time were content with a walnut-shell and a straw. One pipe often sufficed them for a smoking party, the pipe being handed round the table at threepence a pipeful. It is hardly surprising that sore tongues increased rapidly in number. Syphilis at the same time was rife, and the older treatment by mercury was beginning to give place to guaiacum and other less reliable remedies. Syphilis of the tongue, both as a primary lesion and as a late glossitis, soon became well-known to the medical profession.

The practice of smoking was at first essentially English, but it quickly spread to the north of Europe, being probably introduced by our sailors. King James I tried to stop the habit, and in 1604 issued his *Counterblaste to Tobacco*, in which he says that smoking is "A Custome loathsome to the Eye, hatefull to the Nose, harmefull to the braine, dangerous to the lungs, and in the black-stinking fume thereof neerest resembling the horrible Stigian smoke of the pit that is bottomlesse." The *Counterblaste* was useless; but although the custom was well established in London, it took a long time to spread through the country, and as late as 1665 it was noted as something unusual that 'such an one was a smoker of tobacco.'

Alcohol.—It is often said that alcohol in the form of spirits plays some part in the production of cancer of the tongue, but history does not appear to show any close inter-relation between spirit drinking and lingual carcinoma. During the seventeenth century social habits remained very much as they had always been. In London, breakfast was not usually eaten, but a piece of bread with a draught of wine or a cup of beer was taken at a tavern some time in the morning. Dinner was the chief meal of the day, and taverns were used for that purpose nearly as often as we now go to restaurants. The fare was simple but ample, and although men were often "scandalously overserved with liquor," it was usually with wine or beer. Spirits, in the form of Scotch whiskey or French aqua vitæ, were esteemed as early as the sixteenth century, but they were not much drunk until the reign of Elizabeth, nor was any excise duty imposed until 1684, and in that year it was only levied upon a little more than half a million gallons.

Habits changed quickly after the introduction of coffee. Men became interested in learning the news, and frequented the coffee-houses. Coffee-houses in turn gave place to social clubs, where, in place of coffee, a bottle of wine or a bowl of punch became the popular beverage, and the use of spirits thus increased so enormously that during the years 1721–91 the consumption of British spirits alone reached an average of 0·62 gallon per head of the population, an amount which did not include foreign and colonial spirits. The eighteenth century was a jovial, sociable, hard-living age, when men drank spirits freely, kept extraordinarily late hours, and yet were obliged to take much physical exercise owing to the poor facilities for travelling both in town and country. Cancer of the tongue increased in frequency during this period, but not out of proportion, so far as can be ascertained. It seems probable, therefore, that spirit drinking is not an important factor in its causation. During the whole of this period syphilis continued unabated, but it was treated so severely by salivation and diet that many died of the cure.

II. ZOOLOGICAL DISTRIBUTION.

Cancer, as is well known, occurs in many vertebrate animals, from mammals to fish. Its zoological distribution has been the subject of more than one interesting contribution to the reports of the scientific investigations of the Imperial Cancer Research Fund. The types of carcinoma do not differ materially in human beings and in animals, when similar organs are affected.

I have made enquiries of my friend Sir John M'Fadyean, the Principal of the Royal Veterinary College, and of Dr. J. A. Murray, Director of the Imperial Cancer Research Fund, as to the frequency with which cancer of the tongue occurs in animals. Sir John M'Fadyean has had especial facilities for gaining knowledge of this nature, because he asked in 1890 that veterinary surgeons, stockowners, and others would send him all tumours excised by them in order that he might collect information regarding the occurrence of cancer in domesticated animals. The appeal brought him a considerable number of specimens, and he writes to me in 1918, twenty-eight years after this appeal was issued: "In 1890 I published in the *Journal of Comparative Pathology* an account of a case of cancer of the tongue in a cat. It was the first case I had seen in any animal, and since then I have only seen one other case, and that was in the tongue of a horse. The tumour in the horse had been diagnosed during life as one of actinomycosis, but the appearance of the tongue after death was different from actinomycosis as seen in the tongue of cattle, and microscopical examination showed that the case was one of quite typical epithelioma."

The details of Sir John M'Fadyean's first case are as follows: "*Carcinoma of a Cat's Tongue.*—The tumour grew on the tongue of a cat, and was handed to me by Professor Walley. The cat was a male, and aged twelve years. It had been ill for about two months prior to the date at which it was killed, the symptoms observed being discharge of saliva with occasional streaks of blood, difficulty of mastication and deglutition, and progressive emaciation. Microscopical examination showed that the tumour was composed essentially of masses of epithelium burrowing along the lymphatic spaces of the tongue. The epithelium resembled pretty closely that of the deepest layer of the buccal mucous membrane. Each cell had a large nucleus and a deeply staining (carmine) nucleolus. The central cells in the larger masses of epithelium had undergone a colloid degeneration, probably in consequence of defective nutritive supply." *

In like manner, Dr. Murray writes: "I can only recollect two cases of squamous-celled carcinoma linguæ in animals in our material, both in cats."

In 1902 Dr. Anton Sticker published a very elaborate paper 'Ueber den Krebs der Thiere,' † in which he analyzed the occurrence of cancer in 215,037 horses, 5795 cattle, 91,273 dogs, 1732 cats, and many pigs. In this vast collection, cancer of the tongue only occurred in one old dog.

The net result, therefore, is that one horse, three aged cats, and one old dog are known to have died of cancer of the tongue, and in each case it was a squamous-celled carcinoma. Nothing is known of the previous history of these animals.

These figures show that cancer of the tongue occurs in domesticated animals, but so rarely that it is negligible, and that when it occurs it is of the squamous-celled variety, just as it is in the human. It seems fair to assume that cancer of the tongue in domesticated animals at the present time has not increased in frequency, but remains the same as it has always been; and, as I have already said, history appears to show that until the seventeenth century cancer of the tongue was as infrequent in men as it now is in animals.

III. STATISTICAL.

Leaving now the historical and scientific sides of the question, and turning to the statistical aspect, Dr. T. H. G. Stevenson, superintendent of statistics at the Central Register Office, Somerset House, tells me that cancer of the tongue had already attracted the attention of the Registrar-General as early as 1909, when he wrote, "The increase amongst males from cancer of the jaw and especially of the tongue is remarkable, and can scarcely be explained by improved diagnosis. Although cancer of the tongue in its later stages presents little difficulty in diagnosis, the recorded mortality has increased amongst

* *Journal of Comparative Pathology and Therapeutics*, 1890, vol. iii, p. 41; with an illustration of the microscopic appearances.

† *Arch. f. klin. Chir. von Langenbeck*, Bd. 56, 1902, pp. 616, 1023, and 1067.

males by no less than 228 per cent in 41 years. The increase, moreover, is entirely confined to the male sex."* This remarkable statement is based upon the following figures, which show the annual death-rate per million living, 35 years of age and upwards :—

	1868	1888	1909
Males	46·49	77·49	152·54
Females	17·45	12·46	14·97

The increase in the death-rate from cancer of the tongue continued to increase, until in 1915 it had more than trebled since 1868. There was still no material increase for women, and amongst men the increase was chiefly at the higher ages, that is to say, from 65 years upwards. Thus, the mortality between the ages of 65 and 75 was 283 in 1901, and 432 in 1916 ; between 75 and 85 it was 284 in 1901, and 420 in 1916 ; whilst in persons over 85 it was 166 in 1901, and no less than 516 in 1916.

It is a pity that statistics of death from cancer of the tongue are not available before 1868, but Dr. Charles Singer has done something to remedy the omission. He states† that "the death registers referring to the Chelsea Hospital for old soldiers have been examined from the years 1837 to 1910, and among 4,719 deaths of pensioners of the age of 55 and upwards, at least 62 were certified as due to oral cancer. Of these 62, at least 28 were carcinomata of the tongue and floor of the mouth, giving the proportion of deaths due to the last two causes as 6 per 1000."

An examination of the blue-books issued by the General Registrar shows that of the deaths of males over 55 years of age registered in England and Wales during the years 1901–1909, only 3·5 per 1000 deaths were due to cancer of the tongue. Thus, even with the imperfect certification and greater statistical rarity of carcinoma in earlier years, cancer of the tongue appears to have been twice as common among this group of old soldiers as among the general population of comparable age in Britain to-day.

It should be remembered that the pensioners in this series were long-service men, and that, in the earlier years at least, many of them must have been serving in 1817, at a time when Thomas Rose,‡ surgeon to the Coldstream Guards, had nearly persuaded the Army that syphilis could be cured without mercury, a heresy which was supported by Guthrie,§ but was not shared by the soldiers themselves, many of whom bought Liq. Hyd. Perchlor. privately, and thereby made the fortune of a druggist living near their barracks.

Some additional facts can be gleaned from the reports of the Registrar-General.‖ Here is a table showing the ages at which death occurred from cancer of the tongue during the years 1901–1909 in 6257 men and 782 women :—

Age at Death	Males	Females
Under 5 years ..	0	1
„ 10 „ ..	1	0
„ 15 „ ..	1	0
„ 20 „ ..	2	3
„ 25 „ ..	33	53
„ 35 „ ..	427	85
„ 45 „ ..	1626	128
„ 55 „ ..	2143	167
„ 65 „ ..	1485	209
„ 75 „ ..	498	121
85 and upwards ..	41	15
Totals ..	6257	782

* Seventy-second Annual Report, p. xciii.

† *The Quarterly Journal of Medicine*, 1911, vol. v, p. 20.

‡ *Medico-Chir. Trans.*, vol. viii, p. 346.

§ *Ibid.*, p. 545.

‖ Seventy-second Annual Report, pp. lxxxii–lxxxv.

This table shows that the true proportion of males to females affected with cancer of the tongue is 8 to 1. Our hospital statistics give a proportion of 18 to 1; Sir Henry Butlin thought it was 6 to 1. The table also shows that at that time the optimum, or shall I not rather say the pessimum, age for cancer of the tongue is 55–65 in males, and 65–75 in females. The table, to be strictly accurate, should be headed 'Cases of Malignant Disease of the Tongue,' because the two or three cases occurring in very young persons are almost certainly sarcomata and not carcinomata.

The difference in the death-rates of males and females has already been noticed by Dr. Charles Singer, who plotted it out in curves on the accompanying chart (*Chart* 1) which he has kindly allowed me to reproduce from his article, 'A Study of some Factors in the Ætiology of Oral Carcinoma.'* He says, "The death-rate presented by cancer of

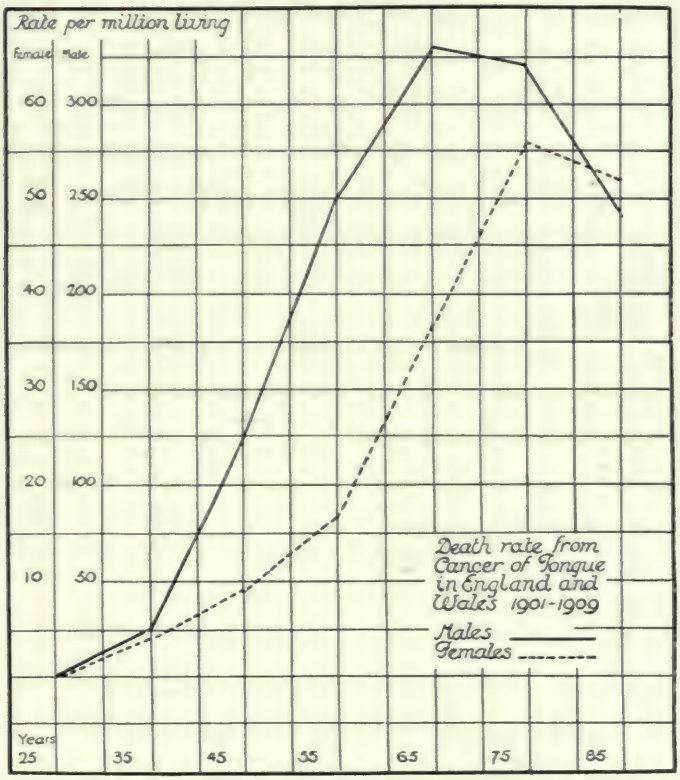


CHART 1.

the tongue has certain peculiarities which are not shared by that of cancer of other parts of the body. It differs, in the first place, from the death-rate from malignant disease of those other parts of the body in which a liability is shared by both sexes, in the marked differences in character of the age incidence of males and of females (*Chart* 1). The death-rate from cancer of the tongue in males rises steadily until about the sixty-fifth year, when the rate remains almost uniform for two decades, to fall again in extreme old age. In the female cases the death-rate rises slowly at first, and by no means parallel to the male; then, becoming accelerated about the sixtieth year, it rises rapidly to a maximum at or about the eightieth year, and again falls slightly (though less than the male curve) at the extreme limit of life.

* *The Quarterly Journal of Medicine*, 1911, vol. v, p. 22.

" The chart illustrating the death-rate from lingual cancer thus presents the following characteristic features: (*a*) The dissimilarity of the male and female curves; (*b*) The approximately equal rates for males in the decades 65–75 and 75–85; (*c*) The drop in extreme old age in both sexes. As regards the general form of the curves presented by this group of cases, it may be said that, while the male curve is a type of its own, the female curve accords fairly well with those for cancer of several other parts of the body, and is, for example, closely similar to the curve for cancer of the rectum in either sex (*Chart* 2)".

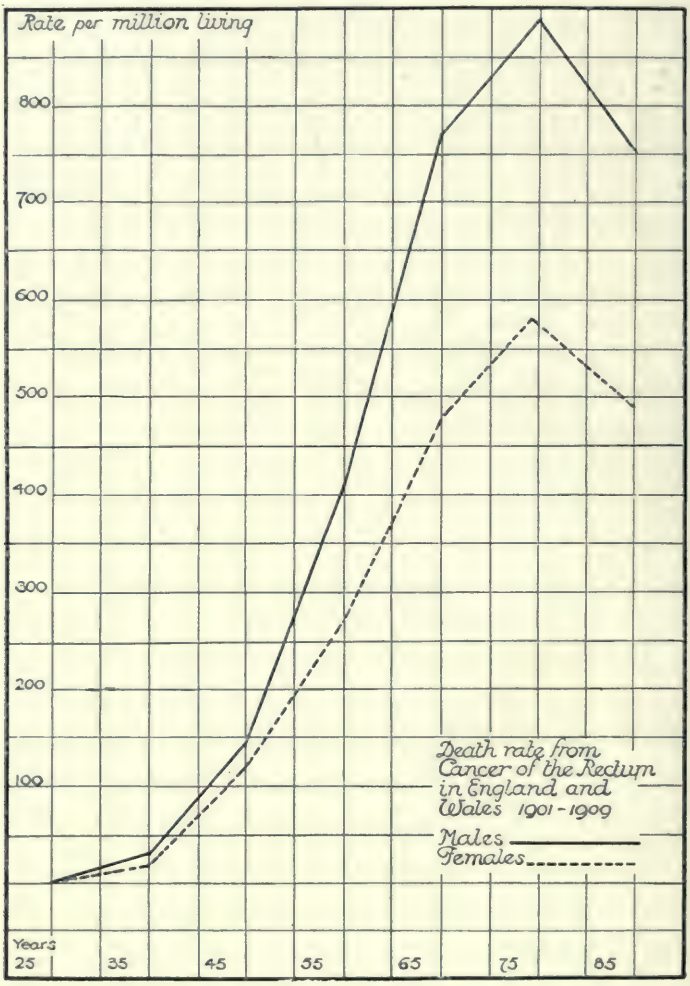


CHART 2.

IV. POSSIBLE FACTORS CAUSING THE INCREASE IN CANCER OF THE TONGUE.

It is clear from the historical and statistical evidence that cancer of the tongue is increasing in frequency, and at the present time it is increasing more rapidly in men than in women. It is of interest, therefore, to try and discover some of the factors which have caused this increase. Irritation is thought to be an important factor in the causation of cancer, and I have therefore been at some pains to ascertain whether the state of the teeth has altered materially since cancer of the tongue became rife, because many patients state that injury to the tongue by a tooth was the origin of the cancer.

a. **Pyorrhœa Alveolaris vel Periodontitis.**—Pyorrhœa is widely distributed throughout the human race, and is often met with in animals under domestication, as well as in wild animals kept in captivity. The animals which have been most carefully observed in regard to pyorrhœa are the horse, the cat, and the dog—the three animals in which cancer of the tongue has occasionally occurred.

Amongst 600 horses working in London, it was found that approximately one-third presented some degree of periodontal disease, mainly of local origin and the result of injury to the mucoperiosteum by foreign bodies in the diet.

Periodontal disease is also extremely prevalent in domestic cats and dogs. It is most frequent in highly-bred cats, because they are fed on soft food, whilst the ordinary domestic cat, which has to get its own living and feeds upon a meat diet, is comparatively free. The same holds true for dogs. Pyorrhœa is seen most commonly in lapdogs and dogs with short muzzles, and especially in the functionless incisor teeth of bulldogs. Dogs living on a good flesh diet which gives plenty of exercise to the jaws are invariably free from the disease. It is clear, therefore, that whilst pyorrhœa may act as a source of irritation to the tongue, it is only of minor importance in producing cancer, as otherwise cats and dogs should be affected much more often than is actually the case.

b. **Caries.**—Caries of the teeth, in like manner, seems to be only of slight importance as a factor in causing cancer of the tongue, although it is often put forward prominently as an exciting cause.

Dental surgeons have done much good work in determining the existence of caries in the teeth of different races from prehistoric times to our day. The late Mr. Mummery examined over 3000 skulls to determine the prevalence of dental caries, and tabulated the results of 1658 cases. Caries occurs from the earliest times, varying in frequency in different districts. Among 68 skulls obtained from Wiltshire barrows, there was only a single case of decay; whilst in 44 skulls from similar long barrows in the more northern parts of England, there were 9 cases of caries.

During the bronze age caries was more frequent, for there were 7 instances in 32 skulls, whilst in the Yorkshiremen of this period there were no less than 26 cases of caries in the 60 skulls examined.

During the Roman period the teeth were often diseased, and in 143 Roman skulls 41 were thus affected, the amount of caries in some individuals being very great; thus, in one woman, aged about thirty, every molar and every bicuspid was diseased. If such a large proportion of Romans in Britain suffered from caries, there is no reason to suppose that the Romans at home were exempt; and if dental caries and stumps were an important cause of cancer of the tongue, it must certainly have attracted the attention of the classical writers on surgery. Yet Celsus, in speaking of ulcers of the tongue, contents himself with following the statement in the *Prorrheticon* of Hippocrates, saying, "Those on the side of the tongue last a very long time, and it should be noticed whether there is a sharp tooth, for this often prevents healing and may need filing." *

In Anglo-Saxon times the proportion of teeth affected with caries was certainly less than in Roman times, and Mr. Mummery states that he only met with it in 12 out of 76 Anglo-Saxon skulls. We have no knowledge of the incidence of dental caries in England from the time of the Conquest until the beginning of the seventeenth century. Mr. J. F. Colyer has now taken up the investigation, and has been examining skulls obtained from the Clare Market district in the immediate neighbourhood of this college. Large numbers of Londoners were buried in the graveyard which occupied this site between the years 1600 and 1800. He tells me that 3443 teeth were present in the skulls which he examined, and 319 of these were carious, the percentage of carious teeth being therefore 9·2 per cent, as against 28 per cent in the Romano-British period. In the skulls and mandibles examined by Mr. Colyer, 669 teeth had been lost from

* Linguæ ulcera . . . quæ in latera ejus nascuntur diutissime durant. Videndumque est num contra dens aliquis acutior sit, qui sanescere sæpe ulcus in eo loco non sinit; ideoque limandus est. Celsus, *Medicinæ*, Lib. vi, cap. xii.

disease. If these specimens are examined more in detail, "we find in the complete dentures 1683 teeth were present, of which 68 were carious, or just over 4 per cent, while in the incomplete dentures there were 1760 teeth present, of which 251 were carious, that is 14·2 per cent. In the latter group 669 teeth were missing, and of these it would be a generous estimate to assume that half were lost from caries, and the other half from periodontal disease. If the estimated carious teeth be added to the known carious teeth, the figures would indicate about one-third carious."

It seems, therefore, as though the proportion of carious teeth amongst modern Londoners is about the same as in Romano-British times. A fallacy lies in the smallness of the numbers under consideration; but if it be assumed for the sake of argument that they are substantially correct, the conclusion must be drawn that, whilst the number of cases of caries has not increased, there has been a very rapid increase in cases of cancer of the tongue. Caries, therefore, is not an important factor in causing lingual carcinoma.

c. **Syphilis and Tobacco.**—None of the factors so far enumerated exercises a preponderating influence upon the increase of cancer of the tongue. It remains, therefore, to consider in somewhat greater detail the two factors pointed out by the history of the disease—syphilis and tobacco.

I have recently examined the records of patients admitted into St. Bartholomew's Hospital suffering from cancer of the tongue during the years 1909–1916. During that period 169 persons entered the Hospital with this disease. Most of them submitted to operation, a few were inoperable, and some discharged themselves after a preliminary examination. The diagnosis of 'squamous-celled carcinoma' was verified in every case operated upon, by an independent microscopical examination carried out in the Pathological Institute attached to the Hospital.

Women.—Of the patients, 9 were women, and 160 men. The proportion of women to men, therefore, was nearly one to eighteen, which, as I have already said, is much smaller than the true proportion as shown—by the returns of the Registrar-General—viz., one woman to eight men.

Seven of the nine women were married, one was unmarried, and the social state of the other is not given. Of the seven married women, one gave a history of syphilis; two had healed syphilitic scars on the body; one was a widow who had only one child alive out of a family of five—the note adds "she looks as if she drank;" one had suffered from leucoplakia of the tongue from the age of 17, and stated that her father had suffered from "an abscess of the brain," of which he was cured by medicine—this was probably a gummatous meningitis, the patient herself being the subject of inherited syphilis; there was no history of syphilis, either acquired or inherited, in the other two married women. The unmarried woman, a nurse aged 42, said that her father died of aneurysm, and that one sister had cancer of the breast. The patient herself, during the same month in which she first noticed the ulcer on her tongue, found that her right eye was fixed in such a manner that she could not turn it outwards—abducent paralysis. This affection of the eye was cured by medicine, and was probably syphilitic in origin.

All the women had bad teeth, and attributed the cancer of the tongue to irritation caused either by the teeth or by a badly-fitting or broken denture. None of them smoked. In none of these cases was a Wassermann test done.

The duration of the disease had varied greatly in these women. In one, a woman of 52, the cancer grew so rapidly that the tongue was removed three weeks after the first occurrence of symptoms; whilst in another patient the tongue had been painful for eleven years before an operation was considered necessary.

There was also an interesting case which may be mentioned here, though it does not belong to the series, as it was under the care of Sir Henry Butlin. The patient was a married woman, age 24, with pyorrhœa. She was admitted to the hospital with a cancer of the tongue dating, as she said, from the irritation of a carious tooth in May, 1898. Sir Henry Butlin removed her tongue on Dec. 9, 1898. She was discharged from the hospital on Jan. 7, 1899, and returned on Jan. 23 of the same year—i.e., only sixteen

days later—with such extensive recurrence that no farther operation could be undertaken. This woman had suffered repeatedly from small ulcers of the tongue before the cancerous ulcer was observed. These ulcers had appeared in crops three or four at a time, but were curable. The case is remarkable, both on account of the youth of the patient and the rapidity of recurrence after removal of the tongue by a surgeon who was especially careful not to do things by halves.

Men.—The men admitted with cancer of the tongue presented some additional and noteworthy points. Their teeth were nearly always bad, but not worse than is usual in the class to which they belong. Many were edentulous, some from age, some because they had their teeth removed after the appearance of the ulcer for which they sought advice. Of the 160 patients, 93, that is to say 58·5 per cent, were syphilitic. Of the 93, 62 gave a history of syphilis, and the remaining 31 showed signs of syphilis in the form of chronic glossitis, aortic disease, scars of healed ulcers, tabes, etc. The syphilis was invariably of long standing and, taking a few cases in the series without selection, the primary infection was said to have been 26 years, 30 years, 29 years, 40 years, 28 years, 23 years, and 43 years previously. Twenty-six of the patients stated definitely that they had never contracted syphilis, but of these one had suffered from gonorrhœa, and two had a positive Wassermann test. Many of the patients had drunk beer to excess, but did not as a rule acknowledge that they had taken spirits freely. There is no doubt, however, that many were, or had been, alcoholic. For instance, one was a farmer who stated that he took thirty glasses of strong beer daily and smoked continuously; he had cancer of the tongue which was removed at the age of 74. Another man, who said that he smoked eighty cigarettes a day, was usually drunk six days a week, and had contracted syphilis twenty years previously, suffered from a richly deserved cancer of the tongue at the age of 42. On the other hand, a teetotaller and non-smoker, who denied that he had ever suffered from syphilis, had his tongue removed for carcinoma at the age of 51.

A Wassermann test was performed 26 times, with the result that in 12 cases it was negative, in 6 positive, in 5 it was doubtfully negative, and in 3 doubtfully positive. These results may be compared with those obtained by Captain Arnold Renshaw, Demonstrator of Pathology at the Manchester University Medical School (who wrote to me at the kind request of Dr. C. H. Browning, Director of the Bland-Sutton Institute of Pathology, Middlesex Hospital), and by Captain Archibald Leitch, Pathologist to the Cancer Hospital, Brompton. Captain Renshaw writes: "Seventeen cases of squamous-celled carcinoma of the tongue were examined, and only two cases showed a positive Wassermann reaction. Two of the negative cases gave negative reactions before and after (twenty-four hours before and forty-eight hours after) an intravenous injection of neosalvarsan, this being repeated in each case after a second injection had been given. In one of these cases there was a definite history of syphilis twenty-five years previously." Captain Leitch writes: "I regret that I cannot give you any definite figures. All I can say is that the majority of cases I tested gave a positive reaction. The numbers tested were comparatively few, merely sufficient to establish in my own mind the fact that the result of a Wassermann reaction was of no service whatever in assisting a diagnosis between syphilis of the tongue and carcinoma of the tongue. Of that I am certain. Strangely enough, I did a few reactions in advanced lingual syphilis, and some of these were quite negative." Carl Bruck* says that he obtained ten positive Wassermann tests in twelve cases of leucoplakia of the tongue.

The Wassermann results are interesting, but too much importance must not be attached to them as signs of active syphilis, because, as Lieutenant-Colonel L. W. Harrison wisely says,† "Although the Wassermann test looks deeper into the patient's condition than the naked eye, it is not an absolute guide to a decision regarding the absence of syphilis."

* *Die Serodiagnose der Syphilis*, Berlin, 1909, p. 70.

† *The Diagnosis and Treatment of Venereal Diseases in General Practice.* The Oxford Medical Publications, 1918, p. 280.

As regards the influence of syphilis upon cancer of the tongue, the number of cases under review is too small to generalize upon, and is only useful to point out the direction in which future work is advisable. There is, moreover, a possible fallacy. It is a matter of common belief that syphilis is in some way associated with cancer of the tongue. Every patient, therefore, is asked as a matter of routine whether or not he has previously suffered from syphilis. This is not done in other surgical diseases, and there is consequently no means of determining what proportion of patients admitted into hospital would acknowledge previous syphilitic infection.

It is not uncommon in a family for two or more members of the same generation to suffer from lingual carcinoma, but it is very rare for a father and son to die of the disease. There is one case in the records at St. Bartholomew's Hospital, but I can find no other. This may mean that the son, born whilst the father has active syphilis, is thereby protected if he does not happen to have leucoplakia; or it may imply that the tissue changes in the tongue which are sufficient predisposing causes in the first generation are compensated in the second generation. The first assumption is the less likely, because inherited syphilis, as has been shown, is actually a factor in cancer of the tongue. The point is in need of further investigation, first as to whether it is a fact, and secondly as to the explanation. Another point for investigation is to determine whether cancer of the tongue occurs more frequently in syphilized members of families predisposed to cancer than in those with no such history. Personally I do not believe that it does.

The evidence seems to point at present to a close association between syphilis and cancer of the tongue. The syphilis may be active; it is more often quiescent or even extinct. It may be inherited; it is more often acquired. In every case the syphilitic infection has preceded the appearance of cancer by very many years, and the preliminary syphilitic changes therefore are slow and prolonged. Of these preliminary changes I know nothing. I have examined many sections of cancerous tongues, but there are no constant histological changes in the deeper tissues which are attributable to the effects of spirochætal infection. Tongues which were leucoplakic at the time of removal show a thickening and fibrosis of the walls of the arterioles, but in others there was no manifest change either in the blood-vessels, the lymphatics, or the connective tissue. An examination for such changes needs more care, a larger amount of material, and much more prolonged study than I have been able to give in the limited time at my disposal. All that can be said at present is that syphilis in some way alters the resisting power of the epithelium of the tongue, and allows the squamous cells to run riot; in other words, that lingual carcinoma is born on the bed prepared by syphilis. A similar relationship has long been known to exist between syphilis and tubercle, but in tuberculosis there is a definite infective agent; as yet there is no proof of any such exciting cause in cancer.

When mercury fell into temporary disrepute in the treatment of syphilis at the end of the sixteenth century, and again in the Army at the beginning of the nineteenth century, it seems that cancer of the tongue increased in frequency. It would be interesting to determine whether the present increase can be associated with the very imperfect treatment of syphilis which was in vogue during the mid-Victorian period. The sound teaching of John Pearson (1758–1826), surgeon to the Lock Hospital, that mercury in sufficient doses was the proper treatment for syphilis,* regulated the practice of most surgeons during the earlier decades of the last century. The introduction of potassium iodide, and its obvious utility in the later stages of syphilis, led to the very imperfect mercurial treatment which continued until our own day. Several of the patients who were treated for syphilis at St. Bartholomew's Hospital, and were admitted for cancer of the tongue forty and fifty years afterwards, stated that they had been given mercury for a fortnight or three weeks only. As late as 1880 the old dread of salivation still lingered, and it was quite usual in the out-patient room to hear a patient protest that he would not take mercury on any account. The treatment at that time was merely a treatment of

* *Observations on the Effect of Various Articles of the Materia Medica in the Cure of Lues Venerea.* London, 1800.

symptoms, and minute doses of the red and green iodides of mercury were frequently prescribed. Is the present great increase in cancer of the tongue amongst old syphilitic patients the aftermath of this treatment?

But if syphilis is a predisposing cause of cancer of the tongue, the exciting cause must be looked for elsewhere, and it ought to be some form of long-continued local irritation. The provocative irritation is sometimes, but not so often as might be expected, syphilitic—the fissures and abrasions of chronic glossitis or the soreness of leucoplakia. Pyorrhœa and carious teeth, as I have shown, are very frequently associated with cancer of the tongue; but had there been no previous syphilis, lingual carcinoma should not have occurred in men and women more often than in the domesticated animals, whose teeth are equally affected by disease. Pyorrhœa and caries are at least as frequent in women as in men, and it is probable that syphilis is just as common, yet cancer of the tongue in women has not yet increased in the same ratio as in men.

It remains, therefore, to inquire whether any change has taken place in the habits of men within the last fifty years which has not affected women to the same extent.

Before 1868, anyone who looks at the pictures in *Punch* will see that snuff-taking was on the wane, and that whilst cigars might be smoked openly in the streets, pipes were taboo in public, and cigarettes were unknown except to foreigners, and travellers who had learnt to smoke them on the Continent or in America. Smoking after dinner was not usual amongst gentlemen who still drank a glass or two of port wine, and in the various Senior Common Rooms to which I was hospitably invited at Oxford during the years 1874–80, the Fellows of the older school only smoked after going to their own rooms. On the other hand, long clay or churchwarden pipes, with a mug of home-brewed beer, solaced the leisure of many country parsons and doctors at the bowling greens and quoit grounds in summer, and round the hearth in winter. The labourer smoked a short clay or cutty as a matter of course. On the whole the upper classes smoked a great deal less than they do at present, whilst the lower classes smoked about the same, but in a more irritating manner so far as the tongue was concerned. From 1877 onwards the smoking of cigarettes has become an ever increasing habit, until now it is well-nigh universal amongst men, women, and boys.

Amongst the patients suffering from cancer of the tongue admitted into St. Bartholomew's Hospital whose cases I analyzed, 37 men stated they had been great smokers, whilst only 2 were non-smokers. It seems possible, therefore, that smoking acts as the exciting cause of cancer in a tongue which has been sufficiently prepared by previous syphilitic infection of the tissues. Smoking acts as an irritant in two ways. My friends have kindly experimented for me, as I do not myself smoke, and they tell me that it causes a definite rise of temperature in the mouth, registerable by the thermometer; and there is also the irritant action of the nicotine itself. Smoking may thus bear the same relation to the production of lingual carcinoma as the brazier does to Kangri cancer.

To sum up, then, I think the following conclusions can be safely arrived at from the evidence I have obtained. Cancer of the tongue has always existed both in men and in animals, the actual cause being as yet unknown. Its rapid increase in men within historical times is the result of two causes: the first predisposing, the second the exciting.

The predisposing cause is the degenerative change taking place as a result of spirochætal infection, the change being accentuated by lapse of years and by indulgence in alcohol. The form in which the alcohol is taken does not seem to be important; beer, spirits, and wine are equally harmful. It is the amount consumed, not the quality, which matters.

The exciting cause is local irritation. The most effective local irritant is tobacco, although pyorrhœa and carious teeth often act as minor exciting causes. The exciting causes may act for long periods of time, but will not produce cancer, except in the rarest instances, without the long-continued action of the predisposing cause—syphilis. The occasional occurrence of cancer of the tongue in animals and in non-syphilized people shows that, as in cancer generally, there is a *tertium quid* as yet undiscovered, which is

called for convenience the predisposition to cancer. This predisposition manifests itself in the varying resistance to cancer shown by different persons. Sometimes the course of the disease is rapid, and an accidental injury to the tongue is quickly followed by a carcinomatous ulcer; at other times, when every factor seems to be present and the individual ought to have cancer of the tongue, he lives to a good old age, and dies of some wholly different disease.

It is this *tertium quid* which we should seek, by correlating, as I have tried to do this afternoon, historical, clinical, and pathological results; for it is only by a wide survey on all sides that it is possible to discover where experimental research is likely to be most useful. Years ago* I carried out a series of experiments to ascertain whether irritation by itself had any influence in producing cancer in animals; but the results were uniformly negative, and some other factor was clearly necessary to make the epithelial cells change their natural method of growth.

CONCLUSION AND FORECAST.

In conclusion, some points of great practical importance are obtainable from what has been stated.

In the first place, it ought to be possible to reduce cancer of the tongue to the subordinate position which it occupied before the seventeenth century in men, and which it still holds amongst the domesticated animals.

At the present time syphilis is more prevalent than it has been for many years, and the consumption of tobacco has risen from seven and a half million pounds in 1914 to eight and a half million pounds in 1915. Much of this tobacco is smoked in the form of cigarettes, and women now smoke on a much larger scale than they used to do. It follows, therefore, that if matters are allowed to continue as they are doing, there will be a huge increase in the number of patients suffering from cancer of the tongue. The increase should begin about 1950, and it should affect women as well as men.

Such an increase can be prevented by a thorough and systematic treatment of syphilis in its initial stages; for, as has been shown, cancer of the tongue has always increased in frequency some years after syphilis has been treated inadequately. Persons who are being treated for syphilis, therefore, should be told never to smoke, not to drink to excess, and to pay regular visits to a dentist in order that their teeth may be kept in the best possible state, and that any dentures they may have to wear should be maintained well-fitting and free from rough edges.

Such advice should be given whilst the patient is actually under treatment for syphilis. It is useless to defer it until the tongue has become sore, because it is then too late in a large number of instances. Many patients, of course, will say that they would rather run the risk of having cancer of the tongue than put up with such a restriction as is involved in renouncing tobacco. It may be so; but at any rate it is our duty to put the matter plainly before them, and to point out the risk they run, in the hope that a few will take advice and be saved from a painful disease and a miserable death.

* *The Journal of Pathology and Bacteriology*, 1898, vol. iv, p. 69.

TREATMENT OF CASES OF FRACTURED FEMUR AT A BASE HOSPITAL IN FRANCE.

By Lieutenant-Colonel VICTOR HURLEY, C.M.G., A.A.M.C., Melbourne, and Major S. H. WEEDON, A.A.M.C., Sydney.

GENERAL OBSERVATIONS.

In the following paper an outline is given of the methods used and the conclusions arrived at in the treatment of 170 cases of fracture of the femur during the six months July to December, 1917. As these cases have been retained under treatment until firm union has occurred, they have been of special interest, in that the results of treatment have been observed in a manner not possible in other war wounds. It has thus been possible to arrive at definite conclusions on the relative merits of different methods of treatment. At the outset, the necessity of specially staffed and equipped wards was recognized as essential, and three such femur wards, with a total capacity of 100 beds, have been in use



Fig. 303.—A special femur ward.

for the greater part of the above period. The wards (*Fig.* 303) were selected so as to be in the same block of buildings and on the same ground level as the operating theatre and the *x*-ray department. The woodwork and ward fittings were constructed by the hospital carpenters, and for many articles of equipment and furniture in these wards the hospital is greatly indebted to the Australian Red Cross Society.

In most of the cases Thomas knee-splints have been used, together with many added devices and appliances, such as foot-pieces, suspension apparatus, etc. Many of these have been adopted from the work of other surgeons, particularly that of Major M. Sinclair,

to whom we are also indebted for much valuable information and advice. Others of the appliances are original as far as we know, and have been found of practical use.

In order that a connected account may be obtained, we propose to outline the treatment employed from the time of the patient's admission until the time of his transfer to England.

CONDITION OF THE PATIENT ON ADMISSION.

The length of time between the receipt of the wound and the patient's admission to the base hospital varies from 36 hours to 7 days. Most of the cases are admitted on the third and fourth days. The condition of the patient on admission, and his subsequent progress, are greatly influenced by the time which has elapsed before the first thorough surgical treatment of his injuries. Almost all have been thus dealt with at a casualty clearing station, where the fracture has been splinted, usually on a straight Thomas splint. The treatment at the various casualty clearing stations has not been uniform ; but in almost all excision of the wound has been performed with varying completeness ; we have noted in our later cases that wounds have been more thoroughly excised than in the earlier ones.

The after-progress of the cases has not satisfied us that the more recently introduced antiseptic lotions and pastes possess any superiority over ordinary soap and water or saline. As a general rule, the least satisfactory cases are those in which ineffective excision of the wound has been performed (and in this we include the wound in the bone), one or other of the antiseptics in vogue at the moment has been applied, and the wound completely sutured without adequate drainage. Conversely, the cases which do best are those in which the wounds have been most thoroughly excised and adequate drainage provided. The importance of these primary surgical principles appears to have been temporarily lost sight of in the search for an ideal solution or paste—which cannot be expected to compensate for or correct faulty surgical technique.

Wounds caused by fragments of shell or bomb (and especially aeroplane bombs) are usually more severely infected than are bullet or shrapnel wounds.

Of the total mortality, 38 per cent occurred within forty-eight hours of admission. Shock, gas gangrene, and complications due to wounds elsewhere, were the most frequent causes of death during this period. In several, the patient's general condition on admission would not permit any further operative interference, and nothing beyond restorative treatment was possible.

TREATMENT ON ADMISSION.

General.—Patients are usually admitted in the late evening or night, and are given a hot meal, after which they generally obtain a sound sleep. The patient is left till the following day on the splint applied at the casualty clearing station, unless there are urgent reasons for operative interference, of which gas infection is the most frequent. The soiled wound dressings are of course removed, the wounds inspected and cleaned, and fresh dressings applied. Where Carrel tubes have been inserted, two-hourly instillation of eusol or Dakin's solution is continued. The improvement in the patient's general condition following a good night's rest, after a fatiguing and often very painful railway journey, is usually marked.

X-Ray Examination. — On the following morning stereoscopic skiagrams of the fracture are taken, and where possible (as in fractures of the middle and lower third) direct lateral views also. In cases in which B.I.P.P. has been applied, the finer points of detail of the fracture, fragments, and foreign bodies are greatly obscured. Examination of the stereoscopic skiagrams by means of a Mackenzie-Davidson viewing apparatus usually shows that the fracture requires further treatment to correct displacement of the fragments ; and it has been our experience that correct alinement can rarely be obtained on a straight Thomas splint, although this is much the best for purposes of transport.

Portable X-ray Apparatus.—In our earlier cases it was necessary to take the patient

to the *x*-ray department ; but later the hospital was supplied with a portable *x*-ray apparatus. This not only obviates moving the patient, but is essential to obtain the best results. When a patient is taken to the *x*-ray department, his suspension and extension arrangements must be dismantled, and the resulting skiagram is practically useless for affording reliable information as to the exact position of his fracture with these in position. During the after-treatment, skiagrams taken with the patient lying in bed, with his suspension and extension apparatus undisturbed, give full information of the exact condition and position at the site of fracture in a way which cannot be ascertained by other methods of examination, however carefully carried out. As will be described in dealing with the ward after-treatment, the later adjustments required to correct accurately the smaller degrees of displacement are carried out and checked in the light of the information obtained from a study of the ward *x*-ray photograph, repeated as many times as necessary.

When should a General Anæsthetic be Administered?—With the information afforded by the *x* rays, together with the result of examination of the wounds and the general condition of the patient, one is able to decide whether a general anæsthetic is necessary. Repeated anæsthetics react unfavourably on the general condition, and should be dispensed with if it is possible to correct the fracture equally well without their use and without causing undue pain. A little more patience is required of the surgeon, and manipulations must be carried out with the utmost gentleness. The unfavourable action of general anæsthetics is particularly noticeable in cases of gas gangrene—due, probably, to diminution of the alkali reserve.

As regards their immediate treatment, cases may be divided into four classes :—

1. Almost all simple fractures, and compound fractures with clean wounds of entry and exit, can usually be put up without an anæsthetic. In the few cases where accurate alinement cannot be obtained, a general anæsthetic may be administered, and the muscular relaxation thus afforded greatly assists the accurate correction of the deformity.

2. In other cases, where the patient's general condition is critical, and there is no immediate indication for further operation on account of spreading sepsis or gas infection, the permanent splinting should be delayed until the general condition has been improved by twenty-four to forty-eight hours' undisturbed rest in bed, together with the usual restorative measures.

3. In cases in which the knee-joint has been directly involved in the original wound, advantage is gained by maintaining absolute rest for the limb, the manipulations necessary to correct the associated fracture deformity involving risks of lighting up infection in the joint. These cases have usually been cleaned up and immobilized on a Thomas splint at the casualty clearing station, and the correction of the fracture should be delayed until the fate of the joint is evident.

In classes 2 and 3, the correction of the deformity can be made in successive stages, with a minimum disturbance of the parts, by : (*a*) Application of foot-piece and glue extension ; (*b*) Gradual flexion of splint at the knee to the required degree by the use of a pair of wrenches ; (*c*) Necessary adjustments of flannel slings.

4. In many cases, however, it is necessary to give the patient a general anæsthetic in order that his wounds may be more thoroughly examined and cleaned up, and his fractured limb placed on the splint on which most of his subsequent treatment is carried out. For many reasons this is done in the operating theatre, not in the ward, even in cases in which simple cleaning and splinting appear to be all that is required. The developed skiagrams are placed in a viewing box in the theatre, and are thus available for ready reference while the fracture is being dealt with.

PROCEDURE IN THE OPERATING THEATRE.

General.—The anæsthesia usually employed is chloroform induction, followed by Shipway's apparatus for the administration of warmed ether and chloroform vapour. In addition to the heating arrangements of the theatre, several hot-water bottles are

distributed about the patient, and he is well packed with blankets. Unnecessary exposure is carefully avoided.

Cleansing of the Limb, etc.—When the patient is well under the anæsthetic, his temporary splint is gently removed and the limb cleaned. It is generally necessary to remove the extension applied at the casualty clearing station. With the wounds protected with sterile gauze, the whole limb is scrubbed with warm water and soap. In cases where a Thomas splint is to be applied to the sound limb, this is dealt with in the same manner as the fractured limb. The limb is shaved, and then cleaned by several applications of spirit.

Some authorities state that it is not necessary to shave the limb, but for the following reasons we always do so: (*a*) It is the best method of thoroughly cleansing and preparing the skin, and adds greatly to the after-comfort of the patient; in many cases the skin is so dirty that it is not possible to cleanse it thoroughly without shaving; (*b*) The development of vermin beneath the extension strip is prevented; (*c*) Less blistering and skin irritation under the extension strip result.

The skin in the neighbourhood of the wound area is painted with 3 per cent picric acid and spirit, and sterile towels are disposed round the wounds. The surgeon and assistant wash up and put on sterile rubber gloves preparatory to dealing with the wound itself.

Surgical Treatment of the Wounds and Fracture.—In most cases, by the time a patient has reached a base hospital little benefit is likely to result from excision of wounds where this has not been thoroughly performed at the casualty clearing station—with the exception of the wound in the bone, which will be discussed later. In almost all cases the wounds and fracture have been dealt with by a casualty clearing station surgeon; but, as already stated, the methods used vary greatly—especially in the thoroughness of excision of the wounds, in the application of particular antiseptics, and in the degree to which primary suture has been then carried out. Where primary suture has been performed after wound excision and the application of some one or other paste or solution, better results would be obtained if it were possible for the surgeon who has operated to keep the case under his own observation for the first few days. The necessity for early evacuation of these cases during periods of rush, and the journey to the base, have much to do with the infected condition of many wounds on arrival. In war surgery, patients pass through the hands of several surgeons; and it should be a principle of treatment that further operations should only be performed in the presence of definite indications. These are, at this stage: (1) *Spreading sepsis or gas infection in incompletely drained wounds*; (2) *Insufficient removal of bone fragments*; (3) *Vascular gangrene of the limb.*

1. Spreading Sepsis or Gas Infection in Incompletely drained Wounds.—In many cases the wound has been firmly packed with gauze which has acted as a plug, blocking wound discharges, and favouring the spread of sepsis in the depths of the wound. This gauze and any sutures present are removed. In some cases this may furnish sufficient drainage, but in many further incisions are necessary. Wherever possible, these are made by extending the wounds or incisions already present. If, however, they are badly situated for drainage, fresh incisions are required, and are usually made on the outer aspect of the limb, along the line of the external intramuscular septum, the fascia lata being incised at right angles. Incisions may be necessary in other regions of the thigh, but in the following situations they are avoided if it is at all possible: (*a*) *Adductor region*, on account of the danger of opening up the tissue planes in the region of the main vessels, and of the difficulty of obtaining free drainage, owing to the depth of the bone from the surface and the unfavourable anatomical arrangement of the muscles; (*b*) *Posterior region*, on account of the position of the sciatic nerve, and the obstruction to drainage caused by the slings supporting the limb in the splint; (*c*) *Popliteal region*, on account of the presence of the popliteal vessels and nerves, and of the difficulty of dealing with sepsis in this area; (*d*) *Buttock*, owing to the tendency for sepsis to spread widely in the gluteal region, and the interference with the subsequent application of the ring of a Thomas splint. Incisions for drainage should be

made to the full extent necessary to expose the whole of the infected area. When they are made—as is almost always the case—on the lateral aspect of the thigh, little subsequent disability need be feared, as the incision is parallel to the length of the limb and the direction of the muscle fibres, and leaves an almost linear scar on healing.

It is rarely necessary to insert tubes for drainage. In cases where the track of the wound passes along an indirect route, drainage is assisted by inserting a folded piece of ordinary rubber-glove tissue.

After securing absolute hæmostasis, the wounds are cleaned with alternate applications of hydrogen peroxide and hot normal saline. Gauze dressings are applied, either dry, or moist out of hot saline. Formerly Carrel tubes and instillation of eusol or Dakin's solution were used in all cases, but latterly only in very septic cases where it was not possible to thoroughly expose all the recesses of the wound. In cases in which thorough drainage has been provided, frequent cleansing of wounds and application of ordinary gauze dressings has given better results. These are also more convenient to work with, and the necessary manipulations of the limb and fracture during the after-treatment are rendered easier.

Gas Infection.—This complication has been frequently met with, and is usually evident on admission or within a few hours. Ninety per cent of the deaths occurring within the first few days have been due to this cause. It is rarely possible to excise the infected tissue, on account of the extent of the infection present; and even in cases where this is localized to a muscle or group of muscles, the dissection required is so extensive that it is rarely practicable, as is sometimes the case in other regions of the body. In the cases fit for operation, rapid amputation is usually performed. Sodium bicarbonate (3 per cent) and glucose (1 per cent) are given intravenously, and later, in the wards, by mouth and rectum.

2. Insufficient Removal of Bone Fragments.—Considerable difference of opinion exists on the question of the degree to which bone fragments should be removed. The practice of French surgeons is to excise them to a much wider degree than is usual with British surgeons. At the casualty clearing station the wounds in the skin and soft parts have generally been excised, and latterly much more thoroughly than previously; but almost always in the case of bone fragments the same systematic attempt to excise devitalized and infected tissues has not been carried out, and further operation for their removal is necessary at the base.

Bone fragments which have been driven into the soft parts for some distance from the site of fracture are removed, as, even if they survive, they will be of no use in the subsequent repair of the bone, and, what is of more importance, they are potent causes of sepsis. In our earlier cases it was the practice to leave any fragment in the region of the fracture which possessed sufficient periosteal attachment to ensure a reasonable chance of its ultimate survival. While a number of these cases healed and obtained good union, yet in a large proportion osteitis at the site of fracture, with formation of sequestra and persistent sinuses, necessitated further operation at a later date. In our later cases we have excised bone fragments more freely, with much advantage, as shown by the more rapid healing of wounds, better callus formation, and less resulting sclerosis of muscles and soft parts, giving a better functional result. The removal of infected bone fragments—and important amongst these are fragments driven into the medullary cavity of the bone—also provides more thorough drainage of the site of fracture. As Colonel Burghard states in his preface to the English translation of *Traitement des Fractures* by Professor R. Leriche: "Put concisely, the position is, that one school regards as its bugbear possible want of union as the result of removal of fragments from an infected fracture, while the other attaches prime importance to the persistent suppuration and loss of function to which the retention of septic fragments is so likely to lead." Non-union in cases of compound fracture of the femur in men of military age is extremely rare, not more than 1 per cent. The capacity of the femur for forming callus is markedly greater than such bones as the tibia and humerus, and even where the separation between the fractured ends of the femur has been as much as three inches, firm union has resulted.

3. Vascular Gangrene of the Limb.—A few cases have been met with in which the limb on admission has shown the signs of ordinary vascular gangrene. The femoral vessels may have been found injured and have been ligated at the casualty clearing station. In other cases there is arrest of circulation in the limb with no direct indications that the injury to the main vessel has been previously evident. These are usually due to partial or even complete tearing of the vessels, followed by occlusion, either by pressure from blood extravasated into the tissues or from thrombosis.

If, at operation, it is found that the femoral vessels are exposed in the wound, the condition of these should be carefully ascertained. In the presence of sepsis, partial lesions of the arterial wall, involving the outer coat only, result almost always in secondary hæmorrhage. Ligature of such an injured artery above and below, in an already infected wound, is so often followed by vascular gangrene that in these cases our practice now is to amputate while the condition of the patient is good, instead of being compelled to do so at a later date when it may fail to save his life. With a comparatively clean wound, the probability of survival of the limb after occlusion of the main vessels is much greater, and the prognosis is better if the artery is involved in Scarpa's triangle or in Hunter's canal than if in the popliteal space. Several cases have been met with in which the femoral vessels were lying exposed in septic wounds but with no evidence of injury to the vessel walls. Secondary hæmorrhage has resulted in a proportion of these : but in a greater number the wounds and fracture have done well.

Two of our cases of simple fracture in the lower third were associated with injury to the main vessel, and in one the knee-joint was distended with blood. In both there was marked extravasation at the site of fracture. The pulse was absent in the tibial arteries in both cases, and did not return during the after-treatment. In both, normal union of the fracture occurred and good functional limbs resulted.

Extreme Degree of Trench Foot.—A few cases of trench foot have been met with. All of these except one were of minor severity, merely delaying the application of the foot-piece for a few days. In one case gangrene was present, necessitating amputation ; the patient's general condition was critical, and as there was considerable sepsis at the site of fracture amputation was performed at this level.



Fig. 304.—Hodgen splint. Compound fracture of upper third of femur, with large buttock wound.

Selection of Splint.—The type of splint used in any particular case is determined by : (1) The position and extent of the wounds in soft parts ; (2) The site of fracture.

Thomas knee-splints have been used in all cases except those with extensive wounds of the buttocks and posterior aspect of the thighs ; and in these a Hodgen splint (*Fig.* 304)

has been applied on the fractured side until the healing of the wound has sufficiently far advanced to permit the application of a Thomas. It is possible to obtain better control of the fracture with the latter splint. In some cases the wounds of the buttocks and pelvis are so extensive that no splinting is possible, and in these a Sinclair net bed (*Fig.* 305) permits of the comfortable nursing of the patient as well as accurate control of the fragments. Bryan's bed was used in some of our earlier cases.

A Thomas splint is selected which fits the patient so that the hand can readily be passed between the limb and the thigh in front. This is usually Size 21 or 23. The



FIG. 305.—Sinclair net bed. This patient was under treatment for multiple wounds with pressure sores, and not for fractured femur.

smaller the ring the easier it is to maintain the splint accurately in apposition with the tuber ischii, and to perform necessary manipulations and adjustments of the fracture. Large rings are less comfortable for the patient, and increase the difficulties of nursing. Before application the leather of the ring of the splint is softened by rubbing it with soft soap or vaseline.

A Thomas knee-splint is applied to each limb in fractures of the head, neck, or upper third of the femur. In fractures below this level a single Thomas is used.

Methods of Extension.—Extension is usually obtained by means of Sinclair's glue, to which is applied a long strip of folded gauze on each side of the limb. Care should be taken that the glue is not too hot ; it should be tested on the forearm before application. The gauze strips should be firmly and evenly applied, and then bandaged without creasing. Irritation and blistering of the skin occurred under the extension strips in a certain proportion of cases (about 10 per cent), and other preparations have been tried, such as ordinary adhesive plaster and mastisol ; but these have shown no advantage over glue. In any method of extension which depends on the adhesion of the extending material to the skin, the pull required has to be maintained over many weeks, and the skin is subjected to a considerable strain. It is this direct mechanical effect which is largely responsible for the irritation and blistering, and consequently care should be taken that the extending force is evenly distributed on both sides of the limb.

In some cases any method of efficient extension from the skin is impossible owing to associated wounds below the site of the fracture of the femur, such as compound fractures or extensive wounds of the soft parts of the leg. For these we have obtained efficient extension by means of a pair of calipers (engineer's) inserted into the condyles of the femur (*Figs.* 306, 307). The type of calipers used and the technique of their introduction are as devised by Major M. Sinclair, who supplied us with our first pair.

The ends of the calipers are straightened, and then bent in at right angles, and the points tapered to be of the same size as that of a medium bone-drill. Over each limb of

the caliper is fitted a tubular metal guard, which allows the point of the caliper to protrude ¼ in. only. On the outer end of this guard is a small flat metal strip, through a hole

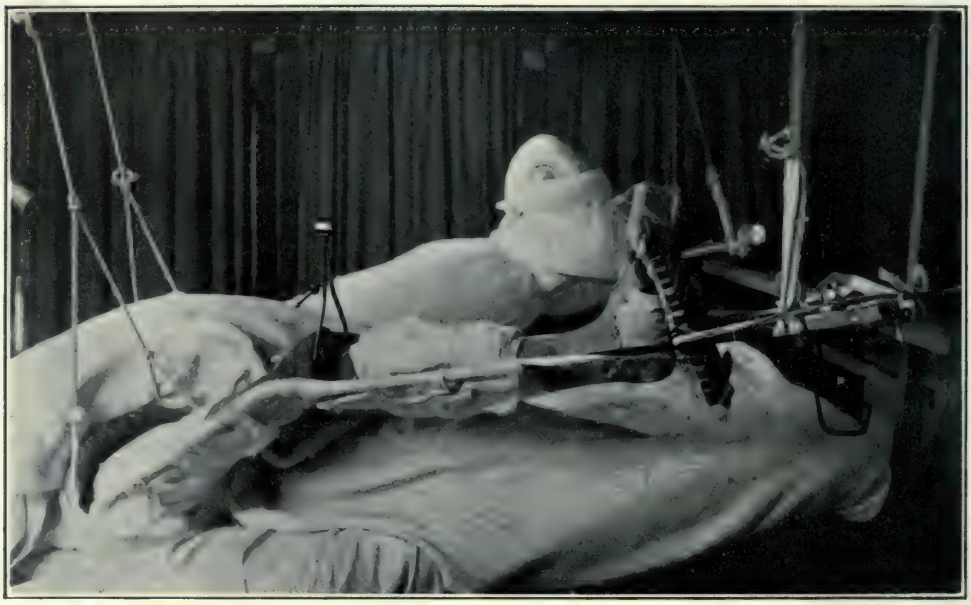


FIG. 306.—Extension by means of calipers inserted into lower end of femur. Compound fracture of upper third of femur, with division of sciatic nerve, and compound fracture of tibia and fibula. (See *Figs.* 307, 310.)



FIG. 307.—Radiogram of calipers inserted into lower end of femur for extension.

in the end of which the extension is taken by means of strong tape. To insert the calipers a general anæsthetic is given and a small incision made down to the bone over the most prominent point of each condyle—this is about one inch from the margin of

the patella on each side, and one inch above the level of the joint. The guards are introduced into the wound, and through the tube the bone is drilled to a depth of $\frac{1}{4}$ in., and the point of the caliper inserted. The advantage of this method is that the cancellous tissue is not tunnelled, as in Hey Groves' and Steinmann's methods, and perfect extension can be obtained.

Some surgeons advocate the routine use of some form of caliper or transfixion method in preference to extension applied to the skin, and claim that subsequent disability of the knee-joint is avoided, as the knee can be freely moved during the after-treatment without interfering with the extension. We prefer the ordinary method of skin extension wherever this is possible, as movements at the knee can still be carried out, as will be described later ; and one avoids the undoubted additional risk of sepsis occurring at the site of operation in patients whose wounds are often already infected.

Foot-pieces.—In all cases a Sinclair wooden foot-piece (*Fig.* 308) is applied to the fractured limb, and a combined foot-piece and bed-rest to the sound limb whenever two Thomas splints are used. To apply the former, five or six strips of flannel, $\frac{3}{4}$ in. wide,



FIG. 308.—Sinclair foot-piece.

with two small curtain rings threaded over each, are glued to the sole and sides of the foot. The rings are arranged to lie along the inner and outer borders of the foot. Cotton-wool is then dabbed over the glued area. The foot-piece is padded with cotton-wool, disposed so as to maintain the normal arch of the foot, and covered with a strip of flannel, the ends of which are fixed to the back by drawing-pins. To each ring is attached a length of tape, the ends of which are passed over the notches on the sides of the foot-piece, and tied together at the back. The foot-piece rides on the side-bars of the Thomas splint by means of an adjustable metal bar, which can be moved up and down in a vertical slot in the foot-piece and clamped in any desired position. Thus, the foot can be raised or lowered, inverted or everted, flexed or extended, and maintained in any desired position by tapes attaching the ends of the cross-bar to the end of the splint. To the sole of the foot of the sound limb a strip of gauze is glued, and attached to the loop at the top of the combined foot-piece and bed-rest.

Materials used for Slinging the Limb in a Thomas Splint.—

1. *Flannel Bandage.*—Each sling is looped around the inner bar of the splint, and fixed on the outer side by means of a large safety-pin or paper clip.

2. *Unbleached Calico*—Has the advantage over flannel that it does not stretch so much, and therefore slings of this material do not require so frequent adjustment. It has not been used as much as flannel, owing to the difficulty in obtaining it.

3. *Jaconet*—Is used by some in the region of the fracture if there is much discharge. We prefer, however, to use sterile flannel or calico slings changed daily. These form part of the dressing itself, the greater part of which is applied outside the sling and kept in place by a triangular bandage. The objections to jaconet are that it is not cleanly, it readily stretches, safety-pins are difficult to insert, and they rust quickly.

4. *Perforated Zinc.*—Strips of perforated zinc covered with flannel are excellent for transport and for simple fractures after the deformity has been corrected.

Application of the Splint.—

1. *Fractures of the Lower Third.*—The deformity in these cases is very constant. The ower fragment is displaced markedly backwards, and slightly inwards, due to the action of the gastrocnemius, popliteus, and adductor magnus. In some the fracture is transverse and situated immediately above the condyle; but in a greater number it is oblique and at a slightly higher level. The main vessels are extremely liable to injury by the sharp spiky end of the lower fragment. Where the obliquity is from behind forwards and upwards, and there is not much shattering, the upper end of the lower fragment may be displaced behind the lower end of the upper fragment, and offer considerable mechanical obstruction to reduction (*Fig.* 309).



FIG. 309.—Comminuted fracture of lower third of femur, with persistent backward displacement of lower fragment; reduction obstructed by sharp lower end of upper fragment.

With the manipulations and extension necessary to correct the deformity, flexion of the hip- and knee-joint is necessary; and in order to counteract the tendency to recurrence of the displacement, the muscles acting on the fragments are relaxed by flexing the splint at the level of the knee-joint 15 to 20 degrees.

It is sometimes stated that by the flexion of the splint in this way the essential principle of the Thomas knee-splint is departed from, and that the Thomas splint then acts in the same way as a Hodgen. The essential principle of the Thomas knee-splint is the fixed extension from the tuber ischii. The more the splint is flexed, the greater is the difficulty of maintaining this fixed extension; but, with the small degree of flexion actually employed, this can still be efficiently carried out, although the extending force is less in the direct line of the limb.

The small size of the lower fragment renders difficult its direct manipulation into accurate position. The following manœuvre, originally shown us by Major Sinclair, is most effective in bringing forward the backwardly displaced upper end of the lower fragment. The ring of the Thomas is slipped over the limb and pushed home against the tuber ischii. A doubly-looped flannel sling is passed beneath the upper end of the lower fragment, and fixed to the splint. The whole lower limb below the site of fracture is levered over this sling, using it as a fulcrum, the leg being extended as much as possible; flexion occurs at the site of fracture, and the backwardly-displaced lower fragment comes forward into position.

The gauze extension-strips are securely tied to the end of the splint while traction

is being maintained, the remaining slings required to support the limb are then placed in position, and the foot-piece is applied as already described.

2. *Fractures of the Middle Third.*—The displacement in these fractures varies. Those towards the upper or lower third show to a lesser degree the respective deformities associated with fractures in these situations. Here also may occur long oblique and spiral fractures associated with axial rotation of fragments, or fractures with total loss of the shaft for some inches. Grooved or incomplete fractures, or clean perforations of the bone, are very much rarer than in the upper or lower third, especially the latter, owing to the different construction of the bone.

For these cases a single Thomas splint flexed opposite the knee is applied, except in those in which the displacement of the upper fragment is similar to that of a fracture in the upper third, when a Thomas splint is also applied to the sound limb. In correcting the displacement, particular care should be taken to restore the normal antero-posterior curve of the shaft of the femur.

3. *Fractures of the Upper Third.*—This class includes those in which the fracture is situated between the neck and a point 4 to 5 in. below the lesser trochanter; and the displacement of fragments varies with the relation of the fracture to the muscular attachments to the trochanters and upper portion of the shaft—in particular, the insertion of the ilio-psoas into the lesser trochanter, and of the glutei and external rotators in the region of the greater trochanter. The commonest type is that below the lesser trochanter, in which the upper fragment is flexed, abducted, and externally rotated. In some the lesser trochanter is completely detached from both fragments; in others the fracture is oblique between the trochanters, so that the ilio-psoas acts on the lower fragment. Even in fractures situated high up in the region of the great trochanters, simple fissuring into the hip-joint rarely occurs, although associated injury to the joint and pelvis (*Fig.* 310) is frequently met with. This, of course, is due to the architectural arrangement of the bony cancelli in the region of the neck of the femur.



FIG. 310.—Comminuted fracture of upper third of femur, with sharp upper end of lower fragment driven into hip-joint. Extension obtained by calipers from lower end of femur. See *Figs.* 306, 307.

In these fractures a Thomas knee-splint is applied to the sound as well as to the fractured limb, in order that the pelvis may be immobilized as far as possible. Both splints are flexed opposite the knee. The accurate correction of the deformity—more especially the abduction—is carried out afterwards in the ward, as will be described later.

In our experience a pair of Thomas knee-splints fixed in abduction has the following advantages over an abduction frame: (*a*) It permits of readier access to the wounds; (*b*) Nursing is easier; (*c*) Varying degrees of abduction, flexion, and rotation can be accurately obtained; (*d*) Skiagrams during the treatment can be taken with the splints in position; (*e*) Patients are more comfortable.

4. *Fractures of the Head and Neck.*—These are often associated with fractures of the pelvis, particularly of the acetabulum or of the pubic or ischial rami. There may also be lesions of the pelvic viscera. As in fractures of the upper third, two Thomas splints are employed, but without flexion at the knee-joint; and the accurate correction of the deformity is carried out in the ward.

WARD AFTER-TREATMENT.

Description of Special Wards.—The after-treatment of cases of compound fracture of the femur is difficult in the absence of special conveniences and appliances. In each of the femur wards was erected a wooden superstructure running the whole length of the ward on each side. The details are shown in *Figs.* 311–315.

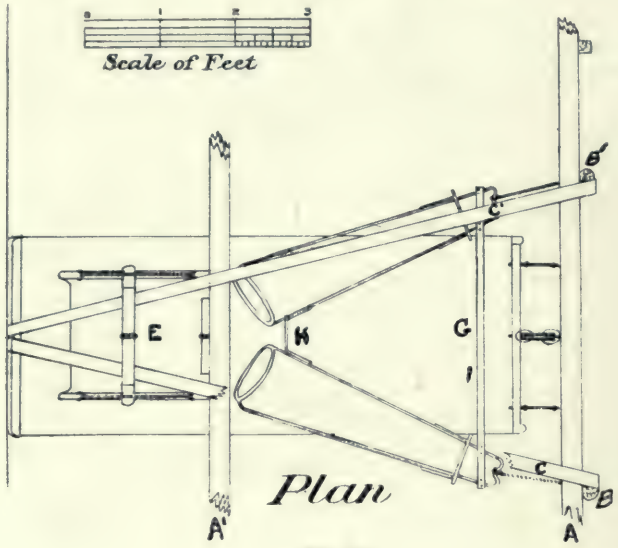


FIG 311.

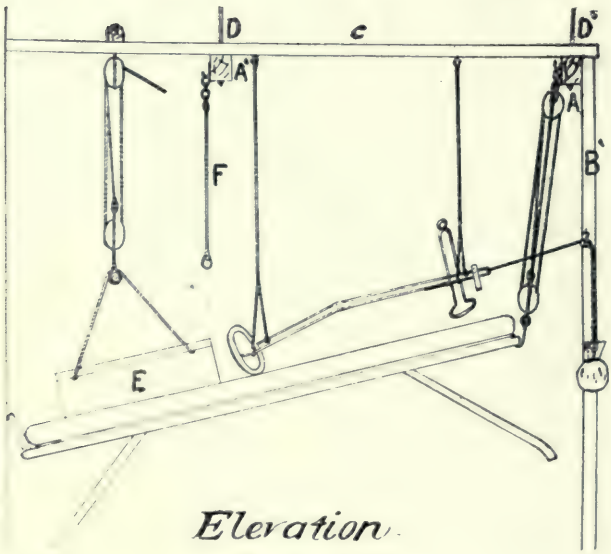


FIG. 312.

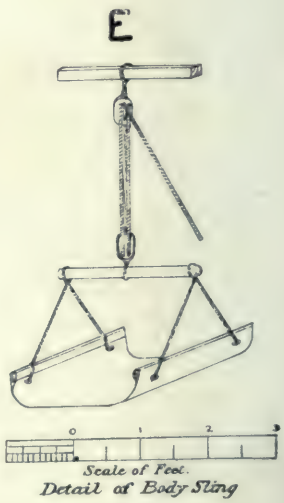
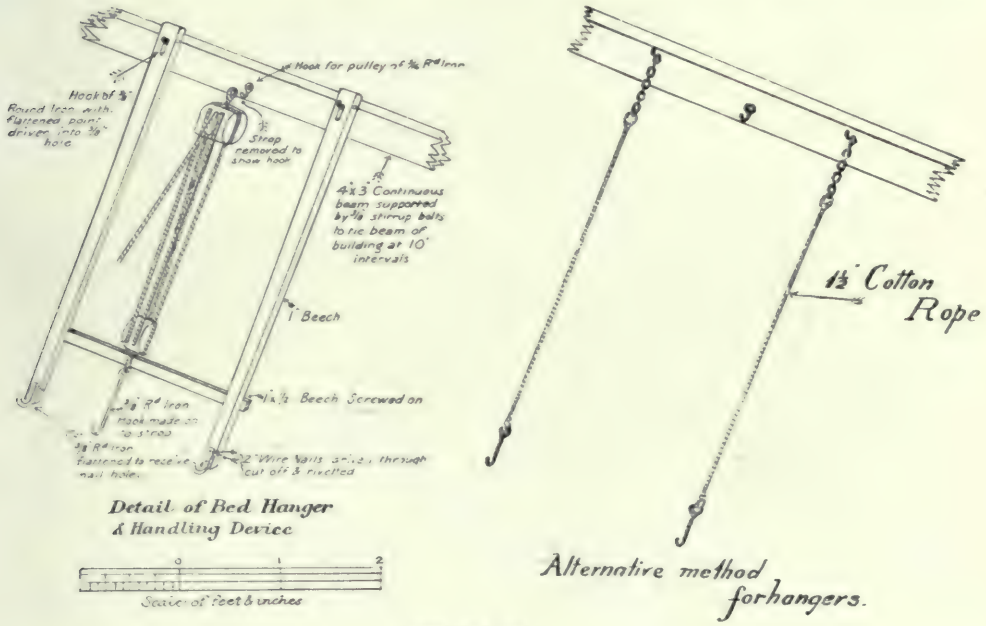


FIG. 313.

Two parallel main beams (4 in. by 3 in.) A and A^1, running lengthwise along the ward are suspended from the tie-beams of the ward 7 ft. above the floor by stout iron rods D and D^1, placed at 10-ft. intervals. A is 7 ft. 6 in. out from the wall of the ward, i.e., 1 ft. beyond the foot of the bed. A^1 is 3 ft. from the wall, i.e. from the head of the bed.

Opposite the foot of each bed are two vertical uprights B and B[1], secured by screws to the floor below and to the main beam A above. These uprights can be fixed in any desired position of separation or approximation. Resting on the main beams A and A[1], are two movable wooden abduction bars C and C[1]. Over the head of the bed these come together and rest on a small wooden block fixed to the wall of the ward opposite the central line of the bed. The abduction bars are attached to A and A[1] by screws, and at the foot of the bed correspond in position to the uprights B and B[1]. These abduction bars are used for the following purposes: (*a*) For the attachments of the necessary hooks and pulleys for suspending the splints; (*b*) For attaching the canvas sling E (*Figs.* 312, 313); (*c*) By altering their angle any required degree of abduction may be obtained. From A[1] opposite the middle line of each bed is suspended a rope and bar F for the



FIGS. 314, 315.

patient to raise himself. Attached to the beam opposite the foot of each bed is a device for keeping the foot of the bed raised (*Figs.* 314, 315). The legs at the head of each bed fit into small blocks which prevent the bed from slipping when the foot is raised. An advantage of the whole arrangement is that the two vertical uprights are the only portions of the structure which rest on the floor, and the floor space between and around the beds is quite free.

Method of Suspension when a Single Thomas Splint has been applied (*Fig.* 316).—White cotton cord ⅓ in. in thickness is used as the suspending material. A loop about 2½ ft. long is attached at each end of the splint. To the centre of this is tied a long piece of cord, the end of which carries a weight. Each cord runs over two pulleys—the first pulley in each case is attached to the abduction bar slightly nearer the head of the patient than the attachment of the corresponding loop to the splint. The second pulleys are attached to the main beam A (*Fig.* 311), just inside the vertical upright, so that the weights are less likely to be disturbed on passing between the beds. The weights used are such that the limb in the splint remains in any position in which it is placed. The weight acting on the upper end of the splint is made a pound or two heavier than that acting on the lower end, so as to assist the patient to raise his pelvis in bed. The weight

and pulley suspension, by allowing a patient to change his position in bed at will, greatly facilitates the nursing, and a certain degree of movement of the hip-joint is permitted.



FIG. 316.—Single Thomas knee-splint suspended by weights and pulleys.



FIG. 317.—Compound fracture of upper third of femur, with large buttock wounds. Hodgen splint to fractured side. Thomas splint on sound limb. See *Figs.* 326, 327.

Method of Suspension when Two Thomas Splints have been applied (*Fig.* 318).—On the patient's return from the theatre :—

1. The foot of the bed is raised. By so doing the counter-extension action of the body-weight is made use of, and the bed is only lowered when it is desired to obtain access to the wound or for the ordinary nursing attentions.

2. To the upper and lower ends of each splint a loop of cord is attached as previously described. The cord from the centre of each loop is tied to a hook in the abduction bar, again slightly nearer the head end than its attachment to the splint. The length of the cord is such that the limbs are just free of the bed, and their tension is so regulated that no sagging occurs when the bed is lowered. At first, suspension by weights and pulleys was used instead of this fixed suspension, but it was found that the same immobilization of the pelvis and splints was not obtained when the bed was lowered.



FIG. 318.—Suspension when two Thomas splints have been applied.

3. The lower ends of the splints are connected by a wooden 'spreader' G (*Fig.* 311). These spreaders are made of lengths from 3 ft. 6 in. upwards, according to the degree of abduction required. The upper ends of the splints are connected by means of an ordinary spring wire foot-piece, which is bound to each inner bar by adhesive strapping. The pelvis is thus efficiently immobilized, and forms the apex of a fixed triangle.

4. To the end of each splint is attached a weight by a cord passing over a pulley fixed to the upright, at such a height that the pull exerted is in the direct line of the splint.



FIG. 319.

FIGS. 319, 320, and 321.—Showing application of sling and lowering of bed to obtain access to wounds or to carry out the ordinary nursing attentions.



FIG. 320.

The weight is so adjusted as to counteract the tendency of the patient to slide towards the head of the bed, especially when the foot of the bed is raised. At first, the ends of the splints were simply tied to the uprights in order to effect this, and also to furnish the fixed point against the counter-extending body-weight. The weight and pulley were later substituted, as they were found more satisfactory for the following reasons: (*a*) The tension of the cord is constant, and does not need frequent readjustment owing to voluntary movements of the patient in bed; (*b*) Owing to the slight give-and-take permitted by the weight and pulley, the Thomas splints are kept in better apposition with the tuber ischii, and the glue extension requires less frequent renewal; (*c*) Where additional extension is desired, extra weight may be used to supplement the fixed extension obtained from the tuber ischii.

Method of Employment in the Nursing of the Patient (*Figs.* 319–321).—When it is necessary to obtain access to the wounds or to carry out the ordinary nursing attention, the canvas sling E (*Fig.* 312) is slipped under the patient's back and adjusted evenly. As will be seen in *Figs.* 320, 321, the sling extends from above the shoulders to below the iliac crests, and particular care should be taken that it takes a firm grip of the



FIG. 321.

pelvis. The sling is attached by two chains on each side to hooks on the abduction bars, or by a block-and-tackle arrangement, shown in *Fig.* 313, so as just to take the weight of the patient. The foot of the bed is then disengaged and lowered. The patient is thus suspended by the sling and the cords attached to the splints. If the sling has been well applied, the relative position of the body and pelvis to the lower limbs is unaltered. No discomfort or pain is caused, and the position may be maintained for any desired length of time. If need be, the whole bed can be removed and be replaced by a fresh one.

Alternative Device for Cases where Two Thomas Splints have been Applied (*Fig.* 322).—In one of the wards cases of fracture of the upper third were treated with the following arrangement, devised by the late Major W. S. Garnett, A.A.M.C. The flexed Thomas splints are applied, and their lower and upper ends connected as already described. The foot of the bed is not raised, and extension is maintained solely by means of the ordinary gauze strips tied to the ends of the splints. The lower ends of the splints are suspended by cords from the abduction bars, while to the ring of each splint is attached a cord

carrying a weight, passing over a pulley. The cord is attached to the anterior part of the ring of the splint diagonally, opposite the ischial tuberosity, and the direction of the pull of the weight is thus upwards and slightly outwards. The weights are so adjusted that when the patient pulls himself up in the canvas sling by means of a block and tackle, the rings of the splints follow the upward movement of the pelvis.

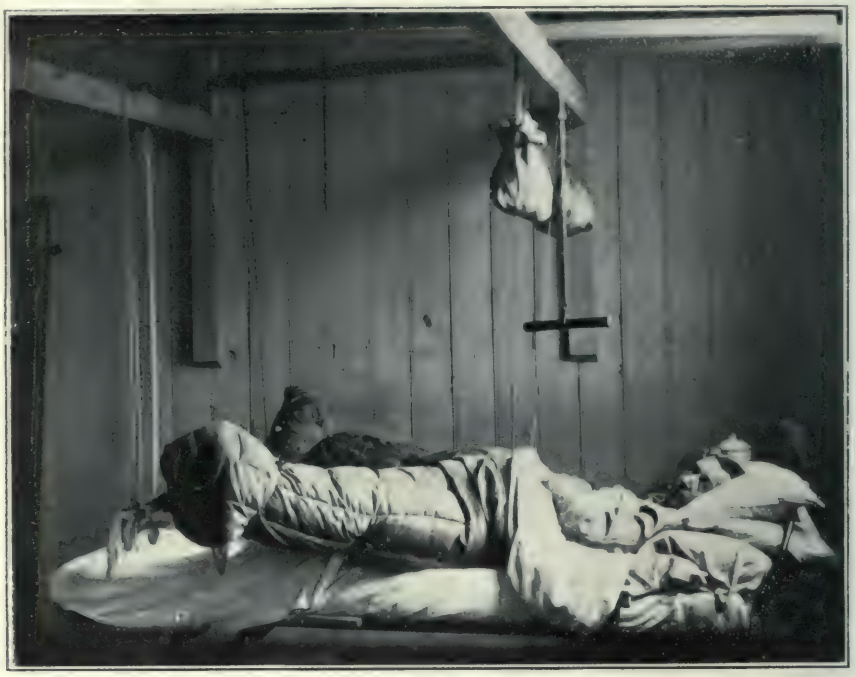


FIG. 322.—Alternative device for suspension of cases where two Thomas splints have been applied.

Treatment of Wounds.—When the dressing is to be done, the slings beneath the wound are unfastened, and it is cleaned up with alternate applications of hydrogen peroxide and saline. A small dry dressing is then applied, and clean sterile slings are fixed in position to the degree of tension required to maintain the corrected position of the fracture. When there is much discharge, the bulk of the dressing is placed outside the slings, and retained in position by a triangular bandage. Where acute sepsis is present, foments of saline or spirit are used. When the wounds have been efficiently cleaned up and effective drainage has been provided, this simple method, carried out as frequently as possible, has given better results than the application of one or other of the recently introduced antiseptics strongly recommended by others. Where wounds are extensive, the dressing is done in sections, so that all slings supporting the fracture are not withdrawn simultaneously.

Treatment Directed to the Fracture.—Within the first day or two, skiagrams are taken by means of the portable *x*-ray apparatus, and the necessary adjustments are performed in order to correct any deformity thereby shown. At periodic intervals further skiagrams are taken, and these give valuable information on the progress of the case.

MAINTENANCE OF EXTENSION.—Care must be taken that extension is efficiently maintained until firm union has occurred. Owing to the elasticity of the skin, and the stretching of the gauze strips by the continuous pull, the extension strips require frequent attention. Various devices have been described for maintaining the requisite tautness

of the extension strips without untying and retying them. Such are the key and screw thread described by Sir Robert Jones in the *British Medical Journal*, 1916, Dec. 16; the tie described by Rankin in the *British Medical Journal*; the twitch by means of a long nail; and the stout piece of rubber tubing attaching the strips to the end of the splint. Of these, the first has been found most suitable.

The extension required to correct the deformity in compound fractures is less than that in most cases of simple fracture; and in some cases of the former, lengthening of the fractured limb can be obtained by degrees of extension which are not excessive. The greater ease of correction of the deformity in compound fractures is due to two reasons: first, because, owing to the shattering and loss of bone at the site of fracture, there are not the same mechanical obstructions to reduction: and secondly, because the power of the muscles is diminished owing to their destruction and subsequent sepsis.



FIG. 323.—Showing extra abduction to correct deformity. Compare *Fig.* 318, showing ordinary abduction.

Lower Third.—In these cases direct lateral skiagrams of the fracture should be taken, to ascertain that the backward deformity remains accurately corrected; although usually when this has once been done, the deformity does not tend to recur as often as in other parts of the bone. Where the backward displacement of the lower fragment has not been entirely corrected, the following may be necessary: (*a*) Increased flexion of the knee; this is done by further bending the splint with a pair of wrenches. (*b*) Increasing the tension of the sling beneath the upper end of the lower fragment. (*c*) Additional extension; the extension exerted by the gauze strips may be supplemented by raising the foot of the bed and attaching weight-and-pulley extension to the end of the splint; this is rarely necessary.

The treatment adopted in those cases in which the knee-joint is involved will be discussed under "Complications."

Middle Third.—Antero-posterior and lateral skiagrams are taken. Even after the fracture has been accurately corrected, continual care is necessary during the whole of the after-treatment, in order that the normal antero-posterior curve of the femur may be maintained until firm union has occurred. In all cases of fracture the limb is frequently measured, to ascertain if shortening is present. The tape measure may show absence of shortening, and an antero-posterior skiagram good alinement, but there may be present a backward instead of the normal forward curve of the shaft. If union occurs in this position, the resulting disability is great. Good position can usually be maintained by regulating the tension of the slings supporting the fracture, but in some cases it may be necessary to exert additional traction on a fragment in a particular direction, e.g.: (*a*) Medially or laterally, by a sling passed round the limb and secured to the side-bar of the splint; (*b*) Antero-posteriorly or obliquely, by the arrangement shown in *Fig.* 320 (right thigh): an ordinary spring wire foot-piece is fixed to the splint near the knee; a straight metal bar is attached to this by one end, and by its other to the ring of the splint; the bar is fixed in the line in which it is desired to exert traction; the sling is passed round the limb and secured to this. This device can also be used in fractures in other parts of the bone.

Upper Third (*Figs.* 324–327).—Stereoscopic skiagrams are taken, as direct lateral views are not possible. As already stated, two Thomas splints are used to immobilize the pelvis as far as possible and to prevent its tilting when the fractured limb is abducted to correct the abduction deformity. On a single Thomas splint it is impossible to prevent the patient from altering the position of his body and pelvis, so defeating the efforts made to keep his fractured limb abducted. Where the skiagram shows that the





FIGS. 324, 325.—Fracture of upper third of femur, showing correction of abduction of upper fragment.

initial abduction is insufficient, the fractured limb is further abducted as already described, and another skiagram taken. This is repeated until sufficient abduction has been obtained (*Figs.* 318, 323). It will be found in some cases that a greater degree of abduction is required in the earlier stages, as the abduction of the upper fragment may become less pronounced at a later date.

Where the skiagram shows that the upper fragment is still flexed in relation to the position of the lower fragment, the following may be necessary in addition to the measures already described: (*a*) Increased flexion of the splint at the knee; (*b*) Raising the level of the lower end of the splint.

As soon as reasonably firm union has occurred in cases where two splints have been applied, the splint is removed from the sound limb, and the fractured limb suspended by weights and pulleys as in cases where a single Thomas splint has been used from the

commencement. At the same time the splint is gradually straightened by means of a pair of wrenches.

Head and Neck.—The treatment of these fractures is the same as for those of the upper third, except that the splints are not flexed at the knee-joint. In six cases, septic arthritis of the hip-joint was associated with the compound fracture. The immediate prognosis in such cases is in marked contrast with that of similar infection of the knee-joint. All the cases met with subsided with immobilization and extension in the abducted position and free drainage. In two cases in which the head of the femur was completely detached, death of the detached head occurred, necessitating removal at a later date. Apparently, even in young men, in the presence of severe sepsis the vascular supply of the head via the ligamentum teres is insufficient to maintain its vitality.





FIGS. 326, 327. Comminuted fracture of upper third of femur, with split down shaft (does not show well in reproduction). Gradual correction of deformity, with final union in good position. Hodgen splint to fractured side. Thomas splint to sound limb. See *Fig.* 317.

Position of the Foot.—This is kept at an angle of 10 to 15 degrees external to the sagittal plane, and at right angles to the leg. The foot is thus maintained in the normal position assumed in walking, and foot-drop is prevented. Where it is necessary to correct axial rotation of the upper fragment, the lower fragment may be externally rotated by increasing the angle made by the foot with the sagittal plane.

Pressure Sores.—The skin of the back and in the region of the ring of the splint requires careful attention, especially over the tuber ischii. Patients are also instructed that they themselves by gentle traction must frequently substitute another portion of skin between the tuber ischii and the ring of the splint. An air cushion has the disadvantage that the patient always tends to work it down between the ring of the splint and the buttock, and so to displace the ring from the tuber ischii. For this reason we have discouraged the use of air cushions as far as possible. With the limb in a flexed splint care must also be taken lest a sore result from continual pressure of a sling behind the knee.

Fracture Boards are inserted beneath the mattress from the pelvis to the head. Frequent changing of the mattress is necessary, as it becomes damp and mouldy on its under surface next the boards.

Covering of the Lower Limbs.—Special arrangements are necessary to keep the exposed lower limbs warm. Small woollen or eider-down quilts serve this purpose excellently.

Movements of Joints during the After-treatment.—It is stated that extension applied through the knee-joint for many weeks in cases of fractured femur is an important factor in causing subsequent stiffness and limitation of movement of the joint. Provided ordinary care is taken, we think that the fear of permanent disability from this cause has been overestimated. Observation of the cases of simple fracture of the femur in this series—all treated by the methods already described—has shown that in all these cases the limitation of movement of the knee-joint which is present when the limb is first removed from the splint, rapidly diminishes with massage and active movements.

In septic compound fractures the condition is more often due to the destruction and subsequent sepsis of the muscles and, to a less extent, of the other soft parts. When one observes the great initial loss of muscle—in many cases right down to the bone—the subsequent formation of inflammatory tissue as a result of sepsis, and the final fibrosis and scarring, one can readily appreciate the important effect these factors have on the subsequent movements of neighbouring joints. This is especially the case as regards the extensor muscles, with their wide origin from the shaft. In some cases the healed skin wound is firmly bound down by fibrous tissue to the subjacent bone, with no muscular tissue intervening. In such cases an attempt to increase the range of movement forcibly results in pain, located at the site of the original wound. In a few of our earlier cases forcible movement under an anæsthetic was performed. The results were not such as to lead us to continue the practice. In these cases, when all signs of acute sepsis had subsided and union was present, the thigh was immobilized as firmly as possible by bandaging in the splint and holding with the hand, and under nitrous oxide anæsthesia the knee was once flexed and fully extended. In two instances sepsis was again lighted up at the site of fracture, and in one, where the wounds were healed, the scar over the bone reopened. In none of them was the final result any better than would have been otherwise obtained.

The cases of permanently stiff knees become very few when one excludes those in which diminished range of movement at the knee-joint is due to : (*a*) Damage to the articular surface, either by fissuring into the joint, or by direct involvement in the wound ; (*b*) Peri-articular infection, with fibrosis and scarring ; or (*c*) Extensive damage to, and subsequent sepsis of, the muscles acting on the joint. Much of the disability which would result from the last class is obviated when free removal of devitalized and infected bone fragments by esquillectomy has been performed in the earlier stages of treatment, and sepsis of the fracture and muscles thereby diminished.

Our practice is as follows :—

Hip-Joint.—In cases on a single counterweighted Thomas splint, small degrees of movement take place at the hip-joint whenever the splint or patient is raised. After reasonably firm union has occurred, the patient is encouraged to sit up and move freely about the bed ; free movement occurs at the hip-joint, and pressure is removed from the skin of his back. In cases where two Thomas splints have been applied, every few days the extension is removed from the sound limb, and the patient made to exercise freely all the muscles and joints. As soon as reasonably firm union has occurred, the splint is removed from the sound limb, the splint on the fractured limb is suspended by weights and pulleys, and the bed lowered.

Knee.—Every few days, after acute sepsis has subsided, the knee is gently moved as follows : A firm grip is taken of the condyles with one hand, and extension exerted. The extension strips are untied, and while the sister holds the splint and thigh at the site of fracture, the leg is gently raised from its flexed position on the splint to full extension. This movement is performed three or four times. The patella is moved as a matter of almost daily routine.

Foot and Ankle.—From the commencement the patient is instructed to perform each day a set number (e.g. 100) of movements of his foot and toes. This is readily

permitted on a Sinclair foot-piece when the tapes attaching it to the end of the splint are untied.

Massage.—Regular massage is carried out by masseurs in each ward.

COMPLICATIONS.

Sepsis.—Further incisions for drainage may be necessary on account of spread of infection causing collections of pus in various situations. The effect of gravity determines to a certain extent the direction of the spread. The commonest direction is up the posterior aspect of the thigh, may be as far as the buttock. Another frequent site is Hunter's canal; the spread is along the course of the femoral vessels, and the infection may spread from here into the region of Scarpa's triangle.

Operation for these conditions—and other secondary operations, e.g. the removal of sequestra—should, whenever possible, be carried out with a minimum disturbance of the limb, by simply removing the necessary slings. It is almost always possible to do this with the limb in the splint and the extension undisturbed.

Secondary Hæmorrhage.—This usually occurs from the 10th to the 20th day, but may occur much later. In one case it occurred twenty weeks after the wound, and was due to erosion of the popliteal artery on the posterior surface of the femur from a focus of infection around a sequestrum. In the majority of cases the site of the wounds and the severity of the hæmorrhage make it evident that the bleeding has occurred from the femoral artery. In these it is our practice to amputate rapidly at the site of fracture, because ligature of the femoral above and below the bleeding point in an already septic compound fracture is so frequently followed by gangrene, which necessitates amputation when the patient's condition is still more unfavourable. If the hæmorrhage has not been alarming, and from the situation of the wounds there is reasonable ground for believing that the bleeding is not arising from the main vessel, the wounds are explored. In some it is possible to identify the bleeding vessel and tie it above and below. In others no further hæmorrhage is seen when the tourniquet is relaxed. In the latter case the wounds are packed with gauze and the patient 'specialled.'

Blood transfusion has been employed in many cases of severe secondary hæmorrhage, and, in addition, is of value in patients who are profoundly anæmic from continued sepsis; in these the general condition is improved and the wounds take on a healthier appearance. The method employed is the indirect one, from vein to vein, by means of paraffin-coated glass flasks. Owng to the difficulty of obtaining Vincent or Kimpton-Brown tubes, we have used large Carrel ampoules with the ends suitably drawn, and have found them perfectly satisfactory. The amount given is from 600 to 900 c.c. *Group IV* donors have been used in all cases, and a few of these are always kept available. Prior to the adoption of blood transfusion, saline solutions were given intravenously, but the improvement in the patient's general condition is transient—not lasting, as in blood transfusion.

Infection of Joints.—In fractures of the lower third of the femur the knee-joint is frequently involved, either by the wound opening directly into the joint, or by a fissure extending from the site of fracture; these fissures may not always be evident in the skiagram. In the former, as already stated, the special treatment directed to the correction of the fracture is delayed until the fate of the knee-joint is determined, and absolute immobilization is maintained. If the knee is obviously infected, the joint is aspirated and the fluid examined. When the infecting organism is streptococcal (especially the long-chained varieties), the prognosis is worst, and ultimate amputation generally becomes necessary. The prognosis is better in cases of anaerobic and coccal infections, in which aspiration followed by washing out of the joint, or drainage by parapatellar incisions, may suffice.

Suppurative arthritis of metastatic origin occurred in six cases, and in one case its incidence in the knee-joint followed on the movement involved in manipulating and re-extending a malunited fracture of the upper third in which signs of acute sepsis

had subsided. The six cases were, shoulder 3, wrist 1, knee 1, ankle 1. In its insidious onset and comparatively favourable prognosis, suppurative pyæmic arthritis is in marked contrast to the septic arthritis resulting from involvement in the wound or from direct spread from the site of fracture. Immobilization and drainage sufficed in all cases. In addition to pyæmic joints, localized pyæmic foci may develop in other situations.

Œdema of the Limb.—Œdema of the leg, foot, and ankle may occur when considerable tension of the slings above the knee is necessary to correct the displacement in fracture of the lower third. The general œdema of the limb which sometimes occurs on its removal from the splint, after union has occurred, subsides in a few days with massage and elevation of the limb.

Tetanus.—Tetanus was met with in four cases. In one, symptoms developed on the eleventh day, and death occurred within thirty-six hours from generalized tetanus. In another, recovery from generalized tetanus occurred, but death took place from secondary hæmorrhage at a later date. In the remaining two the symptoms and signs were localized to the wounded limb, and both recovered. All four cases had received the usual prophylactic injections of antitetanic serum, and all were treated by large doses of antitetanic serum given intramuscularly.

Associated Nerve Injuries.—The only cases met with have been lesions of the sciatic nerve (6 cases), which is especially liable to injury in compound fractures of the upper third. In one case the sciatic nerve was completely divided on the side opposite to that of the fractured limb by a missile which had passed through both thighs; suture of the nerve was performed, but it is too soon to judge with what benefit. In the other cases of complete division of the nerve, varying lengths up to four inches had been lost, and in addition severe sepsis was present. Suture of the nerve was not attempted, beyond connecting the divided ends with catgut to facilitate the identification of the nerve at a possible subsequent operation. Union of the fracture is greatly delayed in these cases; and although the prospect of the patient ultimately having a useful limb is remote, amputation has not been performed on these grounds alone, in the hope that successful nerve grafting may be possible at a later date, or that, even if the limb has eventually to be amputated, it may be possible to do so close to the knee, after firm union of the fracture has occurred, and so give the patient a more useful stump than if amputation had been performed in the first place at the site of fracture, which is usually in the upper third.

In these cases the after-treatment is difficult, owing to the tendency to the development of trophic lesions, rendering extension difficult.

In two cases loss of function in the area of distribution of the external popliteal nerve occurred during the after-treatment, and was probably due to pressure by a sling on the nerve in its exposed situation below the head of the fibula.

Formation of Sequestra.—As previously stated, the formation of sequestra and persistent sepsis are less frequent when careful subperiosteal esquillectomy has been performed. As acute sepsis is so readily lighted up, much harm may be caused by premature surgical interference for the removal of sequestra. Such operations are performed only when it is fairly certain that the sequestra are free. The time at which this occurs varies considerably. It is rarely less than six weeks, but may be much longer, as in cases when necrosis of the ends of the main fragments takes place and the whole thickness of the shaft itself is cast off. The situation and extent of the sequestra are determined as far as possible by *x*-ray examination. The sinuses leading down to them are opened up, and they are removed with as little disturbances of the other tissues as possible. This can usually be done with dressing or sequestrum forceps. No curetting or chiselling of the bone or callus is performed, except in those cases in which it is necessary to enlarge the track leading to a centrally-situated sequestrum. These operations are always performed with the limb on the splint.

Foreign Bodies.—Where free drainage has been provided, no extended search is made at the original operation for foreign bodies shown by the *x* rays, unless they are large

or readily accessible. In the few cases in which persistence of a sinus is due to their presence, they can be readily removed at a later date, when the track leading down to them can be readily followed. This is much preferable to undertaking at the primary operation an extensive dissection for their removal, as large tracts of uninfected tissue may thereby be opened up to infection.

LENGTH OF TIME NECESSARY FOR FIRM UNION.

As the cases treated were all fit men of military age, the ordinary systemic causes of delayed union are of secondary importance. The main factors are: (1) The extent of the original loss of bone; (2) The degree of subsequent sepsis; (3) Accurate reduction of the deformity; (4) Complete division of the sciatic nerve.

In one case of simple fracture of the femur in the lower third, firm union in faulty position was present at the time of admission on the 25th day, and resisted all efforts at correction under an anæsthetic. In this patient there was also a simple fracture of the radius, with synostosis to the ulna in pronation. At an open operation to correct the latter, firm union was found to be present.

In compound fractures where the destruction of the bone has not been great and sepsis is slight, firm union results in 7 to 10 weeks. Union occurs more rapidly in the lower third than in the upper third, and slowest of all in the neck. In cases where the shaft of the bone has been completely destroyed for two to three inches, 15 to 20 weeks or longer may elapse before union occurs.

The proportion of cases in which non-union occurs is probably not greater than 1 per cent, it being of course understood that cases with total loss of the shaft of more than four or five inches have usually been amputated at a casualty clearing station. It sometimes happens that a case which is apparently firmly united when examined on the splint, shows evidence of yielding or bending of the callus when the splint is removed and extension relaxed. This is more likely to occur when the fracture has not been accurately reduced. Usually for the first few days after the extension has been removed the limb is retained in the splint by a bandage.

WALKING CALIPER SPLINT.

Unless military reasons prevent, each patient is retained until he has been able to walk comfortably for two or three weeks on a walking caliper splint (*Fig.* 328). For 10 to 14 days before the splint is fitted, the limb is allowed to rest free in bed supported between sandbags. During this period massage is carried out and the patient performs systematic movements.

Measuring and Fitting.—An ordinary Thomas knee-splint is taken, the ring of which fits the thigh closely. One of the stock sizes can generally be used, and the fit should be such that when the ring of the splint is pushed home against the tuber ischii the fingers can just be inserted between the thigh and the ring of the splint in front. A stock size can be readily altered if necessary.



FIG. 328.—Patient fitted with walking caliper splint.

With the splint accurately applied and firmly pushed home against the tuber ischii, and the foot at right angles to the leg, a point is marked on each side-bar at the level of the sole of the foot. A second mark is made on each bar 1¼ in. below this, and a third mark

$1\frac{1}{4}$ in. below the second, and the bars cut through here. The cut ends of the bars are turned in at right angles at the second mark, so that they come into direct apposition. The patient is fitted with a pair of army boots. The heel of the boot on the fractured side is tunnelled obliquely from side to side. In this tunnel a metal tube is fitted which just admits the inturned ends of the side-bars. The obliquity is such that the hole on the outer side lies 1 in. in advance of that on the inner side. This ensures that the toes are turned out in walking. The heel of the boot on the sound side is built up 1 in., and transverse leather strips are fixed to the soles of each boot to lessen the risk of slipping. The limb is firmly supported in the splint by strips of perforated zinc and bandaging.

Care should be taken that weight is not transmitted through the patient's limb. This may occur from the ring of the splint slipping over the tuber ischii. This tendency



FIG. 329.—Track and steps for initial attempts at walking.

may usually be corrected by slightly flattening and turning over the padding of the ring in contact with the tuber ischii, so as to present a broader, flatter surface. In some cases the side-bars of the splint may be turned in 1 in. or even $\frac{3}{4}$ in. below the level of the sole of the foot.

Careful watch must be made that yielding of the callus does not take place during the initial attempts at walking. This is more liable to occur where union has taken place in faulty position, or where there has been considerable sepsis. In one of the wards a training track has been laid down, and on this patients make their first attempts at walking. On each side of a 10-yard strip of ordinary coir matting is a hand-rail suspended from the roof. The patient is thus able to practise walking himself without the aid of crutches or an orderly. There is also a small flight of matting-covered steps on which the patient practises going up and down stairs (*Fig.* 329).

THE OPERATIVE TREATMENT OF RUPTURED INTERNAL LATERAL LIGAMENT OF THE KNEE.

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The internal lateral ligament of the knee is a large complex structure which forms the inner aspect of the capsule of the knee-joint, of which it is in reality only a thickening. It is usually described as consisting of two definite and distinct portions, a long outer or superficial portion, and a short inner or deep portion; but these two apparently separate structures are only different parts of the same ligament.

It consists of a large bundle of fibres which run from the femur almost vertically down to the tibia. The longer fibres are inserted at the femoral end into a small depression on the inner aspect of the femur just below the adductor tubercle, and at the other end into a wider area on the inner aspect of the shaft of the tibia about one inch below the level of the knee-joint. The deeper short fibres are inserted, like the superficial, into both the femur and the tibia, close to the articular edges of the bones, and in addition have an attachment to the flat inner surface of the internal semilunar cartilage. This attachment of the internal lateral ligament to the internal semilunar cartilage renders the ligament much more complicated in its structure and in its action than is the case with the external lateral ligament, which is only attached to the femur and to the head of the fibula, and has no attachment to the external semilunar cartilage.

In order to understand the action and injuries of the internal lateral ligament, it is necessary to comprehend clearly its structure and points of attachment, especially of the deeper portion, because on this depends largely the occurrence of complications in injuries of the ligament. The deep portion is attached above to the lower end of the femur and below to the upper end of the tibia, in each case close to the articular surface and in combination with the capsule of the joint. In its course it is attached, in association with the capsule, to the inner flat aspect of the internal semilunar cartilage; but the length of the ligament between its attachment to the femur and the cartilage is not the same as that between its attachment to the tibia and the cartilage.

The internal semilunar cartilage is closely bound down to the head of the tibia by its anterior and posterior cornua, and attached round its outer border by the capsule and by the internal lateral ligament, so that in any movement of the knee-joint the cartilage moves in conjunction with the head of the tibia, and only the very slightest amount of movement is present between these two structures, except in the case of an internal derangement of the knee-joint. Between the cartilage and the femur, however, there is movement on any change of position of the joint, so that the portion of the ligament between the femur and the cartilage must necessarily be longer than would be necessary to bridge the space between these two structures when the joint is at rest.

When the knee-joint is fully extended, both parts of the internal lateral ligament are tense, so that no lateral mobility can be obtained in the normal joint. If, however, the joint is flexed to any degree, lateral mobility can be obtained, and this yielding takes place in the internal lateral ligament above its attachment to the internal semilunar cartilage. Similarly, any strain of the internal lateral ligament—whether direct along the course of the fibres, following pressure applied on the outer aspect of the

knee, and so forcing open the joint on its inner side, or laterally by twisting of the joint—comes on the part of the ligament above the cartilage to a much greater degree than on that below.

The internal lateral ligament is usually injured in one or other of the above ways. Thus, a blow on the outer aspect of the fully extended knee may cause partial or, it may be, complete rupture of the ligament. When, on the other hand, the knee is flexed, direct violence on the outer aspect of the knee does not cause so great an injury as when the joint is extended, because the ligament is lax and can yield to the force further than when it is tense with the knee extended. When the ligament is injured with the knee-joint in the straight position, the rupture, whether partial or complete, almost always occurs between the attachment to the femur and to the internal semilunar cartilage, so that the cartilage, which remains closely attached to the head of the tibia, is never displaced by this injury.

On the other hand, a lateral twist of the joint, especially with the knee semiflexed, first puts tension on the upper portion between its femoral and semilunar attachments, and the lateral pull comes on the attachments to the cartilage and to the femur. With the knee straight, the strain on the ligament is taken by the femoral and the tibial attachments, but with the knee flexed, the lower part of the leg is at a different angle to the upper, and thus the strain comes entirely on the cartilaginous attachment. This is accompanied by a rotation of the femur on the tibia which tends to force the cartilage from its attachment; so that the result is usually a displacement of the internal semilunar cartilage, with or without a rupture of the internal lateral ligament.

In any case of injury or strain of the knee-joint, the history of the case, if carefully taken, will usually reveal in what direction the strain on the joint came, whether from the inner or outer side, and whether direct or associated with a rotation of the bones on one another.

Laxity or rupture of the internal lateral ligament is easily diagnosed by the power of abduction of the leg on the fully extended thigh, and if this is present, the history and clinical syndrome should be very carefully studied in order to see whether or not this rupture is associated with some internal derangement of the joint. It is frequently difficult to decide the point definitely, because in many cases, owing to the laxity of the ligament, a fold of capsule may become invaginated between the bones, and symptoms and signs very similar to those of a displaced cartilage are thus caused. When rupture of the internal lateral ligament exists, associated derangement of the knee-joint should only be diagnosed in the presence of clear and unmistakable signs of this derangement, because removal of the internal semilunar cartilage, which is frequently done in these cases, aggravates rather than relieves the condition.

Cases of rupture of the internal lateral ligament are frequently seen in our hospitals, both military and civilian, and varying treatments of the condition are given by different surgeons; but generally the result is not satisfactory, and some form of apparatus to support the knee-joint is usually applied either before or after operation.

The operation usually performed consists in shortening the ligament, with or without a pleating over it of the fascia covering the knee-joint. This operation often results in some temporary benefit to the patient; but the strain of body-weight which is constantly being thrown on the weakened ligament is usually sufficient in a few months completely to reproduce the laxity, rendering necessary some form of apparatus which will more or less perfectly support the inner aspect of the knee-joint.

It was in order to correct this unfortunate state of affairs that the following operation was devised in consultation with Sir Robert Jones, and it has now been performed by me in 10 cases with very satisfactory results and the complete removal of the necessity for any apparatus. These results have lasted in one case for twenty-eight and in another for twenty-five months.

The treatment given depends on whether the lesion of the internal lateral ligament is the only abnormality present in the joint, or whether there is in association

with it a displacement of the internal semilunar cartilage—that is, on whether the rupture of the ligament has occurred above or below its attachment to the cartilage. If there is no doubt that the latter has been detached from its insertion into the upper end of the tibia, it should first be removed through the ordinary antero-internal incision before the treatment of the ruptured ligament is attempted.

Before considering the operative treatment of the condition, it is necessary to fully understand the mechanics of the internal lateral ligament in its relation to the knee-joint and the variations of tension which it undergoes in different positions of the joint. When the knee-joint is fully extended (*Fig.* 330), all the fibres of the liga-



FIG. 330.—Showing the relation of internal lateral ligament to tendons on inner side of normal extended knee.



FIG. 331.—Showing laxity of internal lateral ligament caused by flexion of the knee.

ment are in tension, so that no abduction of the leg on the thigh is permitted in the normal joint. When, however, the knee-joint is flexed, the ligament becomes lax both in the superficial and deep portions (*Fig.* 331). The reason of this is that the distance between the femoral insertion of the internal lateral ligament and the lower articular surface of the bone is greater in the vertical than in any other direction, while on flexion of the knee-joint the femoral insertion is brought downwards and backwards, so that the distance between the femoral and tibial insertions is thereby diminished.

Operation.—This is performed with the leg lying on its outer side and the knee flexed to an angle of 35 or 40 degrees, so that the ligament is in the relaxed condi-

tion and can thus be more successfully tightened. A slightly-curved incision, convex posteriorly, is made from three or four inches above the adductor tubercle to one inch below the tibial insertion of the internal lateral ligament. The anterior flap is reflected forward, and this discloses all the structures on the inner aspect of the joint. Directly in the middle of the operation wound is the loose ligament, which can easily be demonstrated in its entirety. Lying slightly posterior to the joint, and held back by the fascia which covers it, is the sartorius tendon, lying close to the semitendinosus and gracilis. The fascia which secures the sartorius in its normal posterior position should be divided along the whole extent of the operative incision, so that the tendon can now be freely advanced (*Fig.* 332).

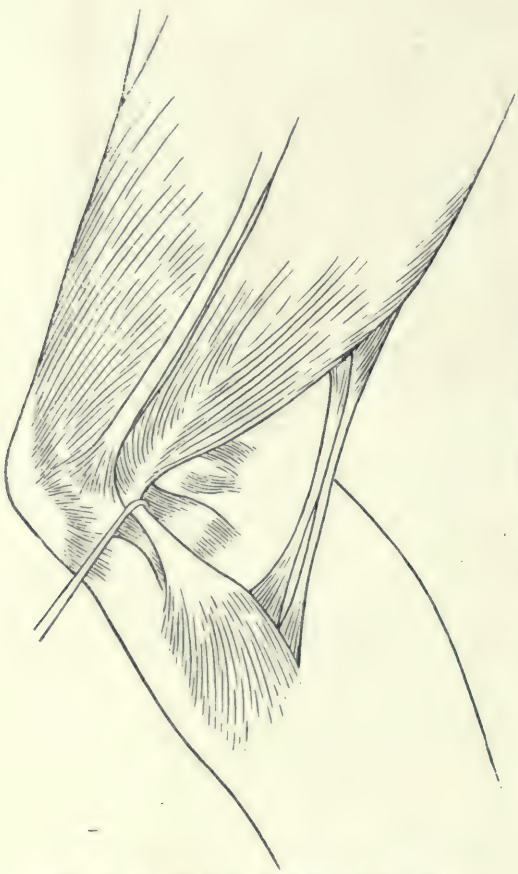


FIG. 332.—Sartorius tendon freed from fascia and brought forward over the internal lateral ligament.



FIG. 333.—Sartorius tendon placed in position in groove in femur between the split upper end of internal lateral ligament.

The femoral insertion of the internal lateral ligament is now clearly defined, a vertical slit about one and a half inches long is made through it down to the bone, and through this slit a small vertical wedge of bone is removed from the femur, large enough to admit of the sartorius being placed into it (*Fig.* 333). This removal of bone is accomplished without interfering to any extent with the attachment of the ligament to the femur, so that no further weakening of the ligament is caused by it.

The sartorius tendon is now pulled forward and laid in the groove in the femur in such a manner that the portion of the tendon between the femur and the tibia is quite tight (*Fig.* 333), and it is then sewn firmly into the groove by stitches passing

through the periosteum and the ligamentous insertion. When this has been accomplished successfully, the outer aspect of the internal lateral ligament is first scarified, and then the ligament is tightened up in the usual manner by suturing adjacent portions of the scarified surface together.

The fascia is now sutured along the line of incision, and skin sutures complete the closure of the operation wound. The knee should then be retained in the semi-flexed position by means of splints or plaster for the next three months, when it will be found that full extension of the leg will be secured in the course of two or three weeks.

The success of the operation depends on keeping the knee in the flexed position during the whole course of the procedure, and the subsequent retention of this position during the minimum period of three months, in order to prevent stretching at the new insertion, which will undoubtedly occur if strain is allowed to fall on it before this interval has elapsed.

The operation results in changing the insertion of the sartorius from the inner aspect of the upper end of the tibia to the inner aspect of the lower end of the femur, and with an active quadriceps it interferes with no action of the knee-joint. The normal action of the sartorius is external rotation of the thigh and slight extension of the leg on the externally rotated thigh. This action is well seen in cases of infantile paralysis where the quadriceps is paralyzed but the sartorius is acting. On attempting to straighten the leg or the thigh, the whole leg and thigh are first rotated outward, owing to the position of the tendon of the sartorius, which lies behind the internal condyle of the femur and pushes this aspect of the lower end of the femur forward; further action of the muscle produces a very weak extension of the leg in this position. This action of the sartorius is duplicated by the external rotators of the thigh inserted into the great trochanter of the femur, and by the very much stronger extension action of the quadriceps. Indeed the power of external rotation of the thigh is in no degree diminished owing to the insertion into the inner aspect of the femur, so that the normal movements of the leg and thigh may be said to be left entirely as they were before.

A PROCEDURE FOR AVOIDING COLOSTOMY AND COLECTOMY.

By A. RENDLE SHORT, Bristol.

One of the commonest causes of acute intestinal obstruction demanding immediate operation is a carcinoma of the cæcum or colon. My procedure in dealing with such cases has changed more than once. There was a period when I performed a right colostomy or cæcostomy, unless the cæcum itself was involved. The only merit of this operation is the ease with which it can be carried out; it leaves the patient with what will often be a permanent artificial anus, which will be a perpetual source of annoyance to him. The great majority of these sufferers would far prefer the slight additional risk at the time of the operation involved in substituting short-circuiting for an artificial anus. My next procedure was to perform lateral ileosigmoidostomy with a Murphy button. This was often satisfactory, but by no means always so. In two out of three cases there followed great and lasting distention of the colon with gas and fæces, giving rise to much discomfort; and one patient died on the twenty-seventh day with gradually increasing distention and occasional vomiting in spite of regular evacuation of the bowels. The distention is no doubt due to the fact that gas and fæces pass the intestinal anastomosis into the cæcum, and are trapped between the ileocæcal valve and the cancer.

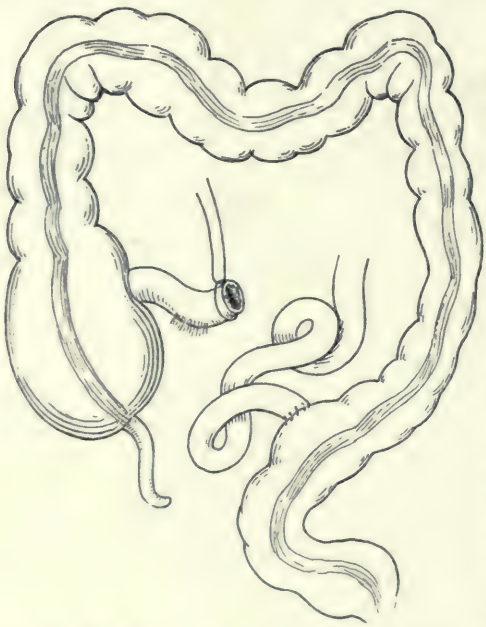


Fig. 334.—Diagram of end-to-side ileosigmoidostomy, with division of the ileum, the distal end being brought out into the wound.

This experience raised the question of an end-to-side ileosigmoidostomy, with division of the ileum. It is well known, however, that this is unsatisfactory, the colon and cæcum becoming filled with gas and fæces by retrograde peristalsis from the site of the anastomosis ('anastalsis' of American writers). I therefore determined to bring out the distal stump of the ileum in the wound, for two reasons: firstly, by passing a catheter through it into the cæcum, the gas could be drawn off; secondly, a wash out of warm water, containing an ounce or two of a magnesium sulphate mixture, could be given through the catheter, which would effectually clear the bowel (*Fig.* 334).

The technique, therefore, is as follows in a case of *Acute Intestinal Obstruction due to Carcinoma of Cæcum or Colon:*

1. Median laparotomy. Verify diagnosis.
2. Division of ileum about four inches from ileocæcal valve.
3. Incision two or three inches deep in mesentery of ileum. Hæmostasis.
4. Trendelenburg position.

5. Proximal end of ileum united by end-to-side anastomosis with Murphy's button to pelvic colon, as high as possible (without going too near the cancer).
6. Closure of abdomen in two layers; distal stump of ileum, with catgut ligature tied round the end, brought out in middle of wound.

If the omega loop of pelvic colon is long and large, the operation is rapid and easy, and the Trendelenburg position is not needed. If the cancer is within two inches of the reflection of the peritoneal floor of the pelvis from the front of the junction of pelvic colon and rectum, the operation is impossible. With the aid of the Trendelenburg position and Murphy's button one can make an anastomosis in many cases where the available pelvic colon is so low down and so tight that the operation would be impossible without their aid.

I am strongly prejudiced against the use of a Murphy button for a small-intestine anastomosis, because it may block the bowel when it passes on; also for a large-intestine anastomosis, because it may itself be blocked by hard fæces. Its use at an ileocolic junction is free from both these objections.

Some of my patients have been troubled with vomiting for two or three days after the operation; this may be relieved by giving pituitary extract or physostigmine salicylate, or by a dose of croton oil and a wash-out through the ileal stump into the cæcum in a really troublesome case. These methods were successful on each occasion. Most of the patients get a transient diarrhœa from deficient absorption of water in the pelvic colon and rectum. This is treated by a few doses of tincture of opium.

The ileal stump does not discharge provided the opening is flush with the skin.

After using the technique above described for patients with acute obstruction, I had a succession of cases in which abdominal exploration for grave symptoms (persistent pain and complete invalidism after appendicectomy; symptoms suggesting cancer of the colon; prolonged incessant vomiting; symptoms somewhat indicative of ureteral calculus) revealed the condition variously described as visceroptosis, chronic intestinal stasis, or cæcum mobile: that is to say, a marked ileal kink, with firm adhesions binding down the ileum a few inches from the ileocæcal valve, a very large, mobile, dropped cæcum, Jackson's pericolic membrane, sagging transverse colon, adhesions slinging up the pelvic colon, and movable kidney. There are grave objections to all the recognized methods of dealing with these cases. Ileosigmoidostomy alone leads to great trouble from retrograde peristalsis filling the colon and cæcum with gas and fæces. Colectomy is, except in the hands of one or two, a dangerous operation. Division of the bands is not curative, and may lead to fatal peritonitis from soakage through of intestinal bacteria. Cæcoplication succeeds well when only the cæcum is at fault, but not when the ileum, transverse colon, and pelvic colon are also involved. I therefore used the same technique which had served me so well in obstruction, except that, time being less urgent and abundance of pelvic colon available, I did not make the anastomosis by means of a Murphy button, but by suturing in the ordinary way over a rubber tube placed in the lumen to avoid kinking.

Three of the four cases appear to be completely relieved of their symptoms, and the fourth, though very neurotic and an invalid of many years' standing, is greatly improved. I promised in each case to close the ileal safety-valve in six months if desired, but it does not appear to give them much trouble.

I observed a day or two ago that a somewhat similar technique is employed by Ochsner in America, instead of colectomy.*

Brief notes are appended of the four cases in which the operation was performed for dropped dilated cæcum with ileal kink, to show the type of symptoms for which I have thought it worth while to operate. I do not advise this procedure merely for constipation, or for distant lesions attributed to toxæmia.

* Ochsner, *Annals of Surgery*, 1917, October, p. 443.

Case 1.—Woman, age 39, sent by Dr. Barber. History of pain in right iliac fossa for nearly two years; has spent many weeks in bed for it. Appendix removed six months before admission without benefit (the appendix was practically normal, except that it was very slender). At the same time a Jackson's pericolic membrane was divided. There has been continuous pain ever since, with constipation, and patient is a neurotic bedridden invalid. Temperature 100·5°, pulse 144. Ileosigmoidostomy performed by technique described on April 12, 1917. Cæcum was very large and dropped into the pelvis; Jackson's pericolic membrane present; transverse colon sagged down into the pelvis.

At the present time patient is a great deal better, but still unable to do much work.

Case 2.—Man, age 48, sent by Dr. Hawkins. History of great loss of flesh (has lost 3 stone), colicky abdominal pain, and constipation, of some years' standing. Patient was much emaciated; visible peristalsis was present; there was no free HCl in gastric juice; bismuth skiagraphy showed general delay. Diagnosed as cancer of the colon. Explored March 26, 1918. No growth present, but cæcum large and dropped, Jackson's pericolic membrane, typical Lane's ileal kink, appendix slung up by a band.

At the present time patient is greatly improved, and has been free from all pain ever since the operation. At first it was necessary to wash out through the ileum, but not after he left the infirmary.

Case 3.—Man, age 37, sent by Dr. Fortescue-Brickdale. Patient was taken ill in February, 1917, and was invalided out of the Army for abdominal pain and vomiting. In July the abdomen was explored by a surgeon and nothing found. He has lost 3 stone in weight, and has now been vomiting every day for weeks in spite of all treatment, and his life is obviously in danger. No abdominal distention; gastric acidity normal; bismuth skiagraphy shows general delay. At operation on April 16, 1918, stomach and other organs were found normal, but cæcum was dropped and dilated, Jackson's pericolic membrane present, appendix absent, marked ileal kink by band two inches from ileocæcal valve.

The patient did excellently after the first few days, during which time it was necessary to wash through. Too much protruding ileum was left, and it had to be trimmed under novocain subsequently. There has been no return of the vomiting.

Case 4.—Woman, age 39, sent by Dr. Crossman. History of pain in the lower left abdomen two years, with constipation and loss of flesh. Has lost 1½ stone in eight months. Skiagram showed what was diagnosed as a ureteral calculus, though before seeing this I concluded that the case was one of visceroptosis. Both kidneys were mobile. On exploration, July 9, 1918, the 'ureteral calculus' proved to be a calcareous mesenteric gland. The pelvic colon was large, and slung up to the iliac fossa by a band of adhesions, dragging on which caused the pain. The cæcum was large and dropped. There was a well-marked ileal kink by band. The transverse colon was very low.

Patient's pain was immediately relieved by the operation, and has not returned.

DISPLACEMENT OF THE MANDIBULAR MENISCUS AND ITS TREATMENT.

By J. HOGARTH PRINGLE, Glasgow

Whilst the menisci of the knee-joint are a very frequent source of trouble, the articular disc of the mandibular articulation is so only on quite rare occasions. In consequence, the symptoms of the latter accident are probably not well known, whereas those of the former are very generally recognized, especially by the members of that class of the community which is particularly prone to be affected; so much so, in fact, that I have now and then thought some of them not only made the diagnosis, but the symptoms as well, for purposes of their own.

I am driven to the belief that displacement of the mandibular disc is a rare accident, because, after personal experience of it on several occasions, I feel convinced that the discomfort, not to say the pain, caused by the occurrence is so extreme, that only the most casual individual would be content to 'carry on' without endeavouring to obtain relief in some way or other.

As in the knee-joint, so in the mandibular articulation, displacement of the meniscus is the result of some sudden movement of the joint, such as is constantly being made by everyone without any untoward effect; so that the rarity of the accident in the one case compared with the other must be due to a large extent to the difference in the anatomical conformation of the two joints, putting aside such predisposing causes as may tend to loosen the cartilage.

In the knee-joint each meniscus is a crescentic structure placed at the periphery of a very shallow concavity; while in the mandibular joint the meniscus is a dome-like, highly concave structure closely and accurately applied to the convexity of the condyle, which may be described as a segment of a cylinder having a quite short radius, and working in the hollow of a deep fossa. In Quain's *Anatomy* the disc is described as being "of oval form, broadest transversely, thickest posteriorly, and thinnest at its centre." This, however, does not appear to be an accurate description. Many years ago I paid a good deal of attention to this disc, and examined a large number in the dissecting-room; and more recently my friend Dr. W. K. Hutton most kindly allowed me to see the mandibular articulation in a considerable number of subjects at Queen Margaret College. What I have invariably found is that there is a very decided central thickening of the disc, situated in its coronal plane over the summit of the condyle (*Figs.* 335, 336). In front of this ridge there is a distinct depression in the disc, which fits the tuberculum articulare of the temporal bone; while below this and anterior to it there is a second thickening, which forms the anterior border of the disc and has the external pterygoid muscle attached to its lowest part (*Figs.* 336, 337). These two thickenings, with the intervening depression, give the superior surface of the disc its typical concavo-convex outline as seen from the lateral aspect (*Fig.* 335), fitting it accurately to the sinuous articular surface of the temporal bone. The posterior portion of the disc tails off from the thick coronal ridge, and lying in close contact with the posterior surface of the condyle, becomes lost in the fibrous tissues of the capsule of the joint.

The disc divides the joint into two cavities, each having its own synovial membrane. In a normal joint the condyle and the meniscus move together in all positions of the joint with a gliding movement which takes place in the superior synovial cavity; whereas between the condyle and the disc itself a movement of rotation takes place in

the lower cavity. As a result of the presence of the two cavities the movements between the mandible and the temporal bone are rendered somewhat complex.

The most important relation of the disc, in view of its displacement, is that it has attached to its thickened anterior border a part of the external pterygoid muscle (*Figs.* 336 and 337). It is, I believe, due to overaction, or irregular action, on the part of this muscle that the disc gets dragged out of its normal position and the symptoms are produced. I call it 'out of position,' because it seems most improbable that any tearing of this disc can ever take place. Tearing or splitting of its tissue is quite commonly the cause of the symptoms that arise in connection with the medial meniscus of the knee-joint; but I do not know of any record of the mandibular disc having been either torn or split; the accident is almost invariably a displacement.

Method of Causation.—The accident is the consequence, in almost every instance, of a sudden and generally excessive action in closing the mouth, such as occurs in the free gratification of an inclination to yawn or sneeze; in a muscular action of this nature, the external pterygoid muscle may do just a little too much, and, as I suggest, drag the disc askew. It may be the result of a violent cough; it is certain that this can happen in the case of a person who has once had one of his discs loosened by a former accident. It



FIG. 335.—Lateral view of the mandibular condyle capped by its articular disc, to show the sinuous outline of the latter and its attachment to the external pterygoid muscle. × 2. (Drawn by Mr. A. K. Maxwell from a recent specimen.)



FIG. 336.—The articular disc has been divided in the sagittal plane, and one half of it removed to show the central and anterior thickenings and the depression between them for the tuberculum articulare. The attachment of the external pterygoid muscle to the anterior thickening of the disc is also shown. × 2. (Drawn by Mr. A. K. Maxwell from a recent specimen.)

can also be caused by a comparatively slight blow on the mandible while the mouth is open. The late Professor Annandale recorded one case produced during the act of vomiting. I have seen two patients who attributed their disability to violent tooth extraction under general anæsthesia.

Owing to the comparative rarity of these cases, one cannot say definitely what actually occurs when the disc is displaced; but from my own sensations I believe that it gets dragged askew—that it goes forwards and inwards, so that its thick central ridge becomes placed obliquely instead of lying in the coronal plane. What is certain is that after displacement the disc acts as a foreign body in the joint: either it gets caught between the rolling condyle and the tuberculum articulare; or it continues to move with the condyle, but in flexion of the joint the condyle and the abnormally-placed disc cannot now clear the articular eminence.

Under the term 'subluxation of the jaw,' Sir Astley Cooper described what appears to be the same condition. In his great *Treatise on Dislocations*, p. 393, he wrote, "as in the knee the thigh-bone is sometimes thrown from the semilunar cartilages, so the jaw appears to occasionally quit the interarticular cartilage of the temporal cavity, slipping before its edge and locking the joint with the mouth slightly opened"; and regarding

the treatment, he says, " Force for removing these appearances must be applied—to give an opportunity for the cartilage to replace itself upon the rounded extremity of the condyloid process." The disc, however, is so closely adapted to the outline of the condyle that it seems to me impossible that the latter could be displaced from it. A comparatively slight twist of the axis of the disc would bring the thick coronal ridge into such a position as would allow it to lock the joint, to the extent that the upper and lower teeth on the affected side could not be brought into contact so long as it remained in its abnormal position.

Symptoms.—When the accident occurs during the progress of a full and satisfactory yawn, for example, the approximation of the teeth proceeds violently and rapidly, and the displaced disc, by intervening between the moving condyle and the temporal bone,



FIG. 337.—Section through the left temporo-mandibular articulation, the mouth being partly open, to show the shape of the articular disc, and the attachment of the external pterygoid muscle to it.

suddenly and abruptly arrests the movement of elevation which the mandible is making at the moment ; closure of the jaws is prevented, and at the same instant the subject of the accident experiences the most acute pain in the region of the joint. The disc is severely crushed between the condyle and the temporal bone, and the tissues around the joint are much overstretched, precisely as occurs in a knee-joint when one of the menisci becomes displaced.

Having recovered from the initial surprise and pain, the patient discovers that if he attempts to close the jaws, the teeth on the affected side will not come quite together, and that any attempt to force them into contact is associated with severe pain at the joint, while there is a definite feeling of a something which prevents the joint from flexing completely. If the disc remains in its abnormal position, mastication is rendered difficult from the beginning, by the pain it induces as well as the mechanical obstruction

it causes. But while a person at the commencement of a meal has great difficulty and pain in chewing, the movements may gradually become easier and less painful, so that by the end of the meal he may possibly consider that everything is right. An hour or so later, however, the pain becomes as bad as ever, and is aggravated by any and every movement that may be made in the affected joint. The explanation is, I take it, that as mastication is persisted in, the disc becomes more and more compressed, only to expand again when the joint remains at comparative rest after the meal, when it can interfere once more with the movements of a joint now rendered tender from the traumatism to which it has been subjected during the process of mastication. Such a compression and expansion would be entirely analogous to that which takes place in the intervertebral discs as the result of the superimposed weight during the erect posture and its removal when a person resumes the horizontal position. Possibly the size and nature of the bolus of food may have something to do with this; a large and rather tough one, which prevents the complete meeting of the teeth in the first instance, may allow the process of chewing to proceed without much trouble, by permitting a gradual compression of the disc, and therefore a gradual approximation of the mandible to the maxilla; while a softer bolus would permit rapid approximation, and so induce more pain.

To a certain degree the pain on movement may be due to effusion into the joint cavities, but it is in the main caused by the stretching of tissues and the squeezing of the disc; the sensation is that of a foreign body which is preventing perfect closure of the jaws. No doubt effusion takes place to some extent, for the external surface of the joint becomes tender to the touch; but I have never been able to satisfy myself that any swelling was present.

In addition to immediate displacement and the rather characteristic symptoms associated with it, some patients are liable to a continually recurring displacement, which is not so acutely painful, but is yet sufficiently distressing; the disc, or disc along with the condyle, slips in and out of position, causing pain as it does so, while at the same time a snap or crack takes place in the joint which is audible to the patient, and sometimes to a bystander as well. This noise in itself may be a source of much annoyance to the sufferer.

Method of Reduction.—The first time I experienced the effects of the injury, the disc remained out of position for several days, during which time many fruitless attempts were made to reduce it. I managed in the end to get it back into position by keeping up hard pressure at the back of the condyle with the mouth open, and slowly closing the jaw. Since then I have always succeeded by the same process, although it sometimes requires to be repeated several times; the moment it succeeds, the sensation of a foreign body in the joint disappears at once.

I have seen four patients who suffered from a similar condition. Two were medical students, and they at once appreciated my explanation of their discomfort when I showed them how to get rid of it. The other two patients were young women whose discomfort resulted from the extraction of teeth under general anæsthesia. In one of them I was able to reduce the displacement, and—for a long period, at any rate—the patient remained free from recurrence. In the case of the other, whose condition was of longer standing, although I was able to effect a reduction by manipulation, the disc continued to slip, and her state was rendered so miserable in consequence that she consented to an operation.

In recurring cases, the tissues, ligaments, muscles, etc., around the joint probably become so relaxed that it is impossible to maintain the disc in position, and it 'comes out' whenever the patient opens the mouth widely. For these patients the only means of treatment is by operation.

The literature of this subject is meagre in the extreme; the only cases known to me are those recorded by the late Professor Annandale (*Lancet*, 1887, vol. i) and those mentioned by Professor Perthes in his valuable contribution to *Deutsche Chirurgie* on the "Injuries and Diseases of the Jaw," which appear to have been of this nature. No method of reducing the displacement by manipulation has hitherto been published to

my knowledge. Mr. Annandale's cases were both recurrent ones, and he treated them by operation, suturing the 'loose' disc to the periosteum; as far as I am aware, these are the only cases that have been reported in which operation has been carried out.

I have only seen one patient whose condition was sufficiently bad to warrant me in advising an operation. She was a domestic servant, age 20, and was first seen in May, 1910, complaining of pain and a loud cracking noise in the left mandibular articulation, both of which she attributed to the extraction of some teeth from the mandible at the beginning of that year. She often has difficulty in closing the teeth after experiencing this cracking sensation. The pain is associated with the cracking noise and is made worse by mastication. She says she feels that something 'comes out' in the left joint on these occasions, and that sometimes it 'goes in' quite suddenly, and then she is at once free from discomfort.

It was very obvious that some object was in an abnormal position in her left joint; the cracking sound she complained of could be distinctly heard when she closed her jaws, and the snap was associated with pain which made her wince. This noise, as a finger placed over her joint at once appreciated, was due to the fact that when she closed her jaws the left condyle of the mandible (or the condyle with its disc) 'jumped' some object immediately before the movement was completed. I was able to reduce the displacement in the manner already described.

She was seen again in June, 1911. The left joint had been giving her a great deal of trouble again, and causing much pain at times. The tendency for the disc to become displaced had become much greater, and it had caused her so great and frequent inconvenience that she had been obliged to give up her situation more than once in consequence, and it continually interfered with her taking food. She was quite willing to have an operation for the condition. She thought that her right joint had recently become affected in the same manner.

On June 12, I excised the disc of the left joint; it was remarkably loose, and could be dragged freely over the condyle in whatever position we placed the mandible. The joint surfaces of the bones did not show any abnormality as far as could be seen, and certainly nothing like what one would expect to see in an osteo-arthritis. She went out with the wound healed on June 26, and was seen from time to time up to May, 1913, when she said she was free from pain and inconvenience in the left joint, and could take food with comfort again; the right joint had only very occasionally given her any trouble since she was operated upon.

SECONDARY JEJUNAL AND GASTRO-JEJUNAL ULCERATION.

By GARNETT WRIGHT, Manchester.

The occasional occurrence of ulceration of the jejunum or the anastomosis after the operation of gastro-enterostomy is a serious drawback to an otherwise valuable operation, and this is especially so in view of the fact that the complication is usually more serious and entails more severe operative measures than the original condition for which the gastro-enterostomy was done.

I have met with three examples of the condition in the past twelve months, two in patients of my own, and one in the patient of another surgeon, and have been impressed by the gravity and intractability of this troublesome complication. In consequence, I have made a careful study of the literature, in the hope of arriving at the cause, in order to minimize the risk in the future.

My first case is a remarkable one, and worthy of record on account of a rare pathological lesion of the stomach, in addition to the secondary ulceration which followed a gastro-enterostomy.

Case 1 (No. 120*).—J. R. C., male, age 32, was referred to me by a medical colleague at the Ancoats Hospital in September, 1910. For eighteen months he had had pain in the right lower abdomen. The pain, which was of a dull, aching character, was practically continuous, though he had exacerbations from time to time. One such outbreak eight months before had lasted four days. There was no constipation. On examination of the patient, nothing was discovered except tenderness on deep pressure over the appendix.

First Operation, Sept. 5, 1910.—A diagnosis of chronic appendicitis was made, and laparotomy through a McBurney's incision was performed, a long appendix containing several concretions being removed. A red mass was observed in the centre of the abdomen, extending downwards into the pelvis. This was very vascular, and began to bleed when touched by the finger. Accordingly the McBurney's incision was closed, and the abdomen was opened in the middle line. The mass proved to be a large soft tumour occupying the greater part of the large omentum. It was continuous (by a pedicle about half an inch in diameter) with a tumour the size of a walnut in the greater curvature of the stomach. The vessels on the greater curvature were much enlarged to supply the tumour. These were secured on each side, and a wedge of stomach containing the tumour was excised. When the wedge was completed, it was found to extend entirely across the stomach. The tumour of the omentum and stomach was removed, and the divided ends of the stomach were united. The abdomen was closed, and the patient made an uneventful recovery.

The *specimen* removed consists of a portion of stomach, with a tumour originating in the submucous coat about the size of a walnut. The mucous membrane is intact over the tumour. This tumour is connected by a pedicle half an inch in diameter, running directly from the greater curvature (probably along a blood-vessel) to a large tumour seven or eight inches in diameter in the great omentum; attached to the lower end of this tumour is a cyst the size of a Tangerine orange. The hardened specimen has been sliced to show the naked-eye characters of the growth, which has the curious 'marbled' appearance seen in hypernephromata. Microscopically, the growth is an endothelioma.

The subsequent history of this patient is remarkable. He consulted me once or twice complaining of indigestion. The symptoms were chiefly pain coming on immediately after food, and sometimes relieved by food, and a great deal of acidity and heartburn. On questioning him later, it was found that he had had similar indigestion since boyhood, though this fact was not elicited at the time. He had no vomiting at all until early in 1916, when he began to suffer from vomiting of the obstructive type, viz., large quantities at a time, night vomiting, etc. He came to see me early in May, 1916, and a diagnosis of obstruction, probably at the site of the old operation, was made.

He was admitted to the Salford Royal Hospital, and radiographic examination by Dr. Bythell showed that the obstruction was at the pylorus.

* The numbers in brackets refer to the *List of Cases* at the end of the paper.

Second Operation, May 6, 1916.—When the abdomen was opened, the stomach was found to be greatly enlarged, and the cicatrix of the previous transverse gastrectomy was clearly visible. There was a very tight stenosis at the pylorus, following the contraction of an ulcer on the upper margin of the duodenum, just beyond the pyloric ring. The contraction had spread in a curious V-shaped manner, isolating a small pouch of the duodenum. As there were some adhesions in the lesser sac, an anterior gastro-enterostomy was performed, a double row of continuous silk suture being used.

The patient made an uneventful recovery, and had complete relief from symptoms until October, 1916. Then he had a sudden acute pain in the abdomen, lasting a few hours. A few weeks later he had a similar slight attack of pain, and after that he began to have chronic pain in the abdomen. It was not related to food, but was brought on when he got into certain positions. For example, he always had pain when he lay on his right side. There was a well-defined tender spot over the left upper rectus muscle, just above the umbilicus. A diagnosis of jejunal ulcer was made, and as the symptoms persisted, I decided to operate.

Third Operation, Dec. 9, 1916.—There was an ulcer on the efferent loop of the jejunum, just beyond the anastomosis. This ulcer was adherent by a single adhesion to the anterior abdominal wall. When the adhesion was divided, the lumen of the bowel was opened, and presenting through the opening was the knot of a silk suture. The silk was removed and the ulcer was infolded, in the hope that it might heal when the irritation of the silk was removed. After recovery patient was dieted and given alkalies and pure olive oil in order to reduce the acidity of his gastric contents, as acidity was still a prominent symptom with him.

He remained free from pain until July, 1917, and then he began to have slight attacks of pain. He had arranged to come to see me again, when he suddenly perforated at his home in Leeds on Oct. 3, 1917, and was taken to the Leeds Infirmary and there operated on by Mr. Richardson, who sutured the ulcer. His pain still persisted, and he again had evidence of adhesion of the ulcer to the abdominal wall, viz., pain brought on by lying on his right side. I therefore advised him to submit to a further operation.

Fourth Operation, Nov. 29, 1917.—The ulcer, still situated in the same place, was again adherent to the anterior abdominal wall. The adhesion was divided, and the anastomosis was undone, the opening in the stomach being closed with two long rows of sutures. The affected portion of the jejunum was next excised, the ends being infolded, and a lateral anastomosis was made. A posterior gastro-enterostomy was then established in the ordinary way through the transverse mesocolon, catgut alone being used for both rows of sutures. The adhesions in the lesser sac were not so troublesome as I had feared at the original operation of gastro-enterostomy, and the operation did not present much difficulty. There was very little shock, and the patient made an excellent recovery.

At the present time (August, 1918) he is still free from symptoms.

This case gains additional interest from the fact that the patient had one of the rare external polypoidal tumours of the stomach. The origin of the tumour in this case was from the submucous coat; and though it was malignant in nature, the patient was free from any sign of recurrence at the last operation, seven years after its removal.

Case 2 (No. 121).—This patient is one on whom I operated for Mr. H. H. Rayner, whose notes on the case, before the man came under my care, are as follows:—

"I performed a posterior gastro-enterostomy—no-loop—on this man in December, 1915, for chronic duodenal ulcer, of which there was marked evidence at time of operation. Linen thread was used for the anastomosis (two layers). After a few months' relief, the pain and epigastric tenderness returned, and in consequence I explored his abdomen in September, 1916; marked induration about the gastrojejunal anastomosis was found, evidently due to ulceration. An anastomosis between the afferent and efferent loops of jejunum was effected, and in performing this a length of linen thread was observed hanging down from the previous anastomotic site. As soon as the man resumed an active life, his symptoms all returned, and this time were more intense and severe than before the first operation; after examining him in September, 1917, I decided to undo the gastrojejunal anastomosis, and so shut the small intestine off from any direct communication with the stomach; however, before the man could be admitted to hospital I left Manchester for service abroad, and Mr. Wright at my request kindly undertook the care of the man."

On Dec. 22, 1917, I operated on him in the Salford Royal Hospital. I found much thickening of the stomach and bowel at the anastomosis, and thickening and shrinkage of the transverse mesocolon. The anastomosis, which was contracted, was undone, and the defects in the stomach and bowel were closed. The old duodenal ulcer was excised by an elliptical incision, which was afterwards closed transversely. As there was no stenosis, no new short-circuiting operation was done.

The patient made an uneventful recovery, and is now free from symptoms (August, 1918).

Case 3 (No. 122).—A man, age 43, was under my care in Salford Royal Hospital in January, 1912, for a perforated duodenal ulcer. The perforation was sutured, the ulcer being infolded, and a no-loop posterior gastro-enterostomy was done, silk being used for both layers of sutures.

He remained well for two years, and then began to have pain coming on shortly after food. At first the pain was only slight, but it gradually increased in severity. At times he could get relief by taking a little warm milk, but this was not always so. He never vomited, and never had any melæna, but he gradually lost flesh, and his life was miserable on account of the constant pain.

He was re-admitted to hospital on April 24, 1918. His condition at that time was one of considerable emaciation, and he had very definite tenderness and rigidity of the left upper rectus muscle. Secondary ulceration was diagnosed, and on April 25 I re-opened the abdomen. There was much thickening of the stomach and bowel at the site of the anastomosis, and the mesocolon in the neighbourhood was also thickened. With considerable difficulty the anastomosis was resected, the defect in the stomach sutured, and the cut ends of the jejunum were united end-to-end. There were numerous adhesions from the old perforation, and the condition of the pylorus and duodenum could not be made out clearly; but it was decided not to do any short-circuiting operation, as the patient was not in a condition to stand it. The abdomen was therefore closed.

The patient made a good recovery, and radiographic examination later showed that there was no stenosis of the pylorus or duodenum, so that no further operative treatment is considered necessary. At the present time (August, 1918) he is free from symptoms.

The *specimen* removed shows secondary contraction of the stoma, with several ulcers situated exactly on the anastomosis. No silk was present, either in the ulcers or in the tissues. Microscopic examination failed to reveal any trace of either layer of sutures, so that both layers had evidently been cast off.

SITUATION OF THE ULCER.

Jejunal ulcers were classified by Paterson into two types according to their situation: (1) Gastrojejunal, when the ulceration was on the line of the anastomosis; (2) True jejunal ulceration. He drew a distinction in the etiology of these two types, stating that gastrojejunal ulceration is largely due to failure in operative technique, while the true jejunal ulcer primarily results from the action of non-inactivated gastric contents on the jejunal mucosa. Moynihan supports this view, which, however, I hope to prove later is only partially true.

The true jejunal ulcers are usually situated on the efferent jejunal loop, nearly always within a short distance of the gastro-enterostomy, but occasionally several inches away. In a fair proportion of cases they are directly opposite the gastro-enterostomy. Very rarely indeed they are in the afferent loop. In some cases multiple ulcers are present.

According to Paterson, about one-third of the ulcers are gastrojejunal, and the rest jejunal. The published reports do not state the exact situation very clearly in many of the cases, but from a study of these, I find that, out of 142 instances, the ulceration was of the gastrojejunal type in 63 (that is, 44·3 per cent); in 10 the ulcer was situated opposite the gastro-enterostomy; in 54 it was on the efferent loop; in 2 on the afferent loop; on 9 occasions there were multiple ulcers; and in 4 cases the site of the ulcer was not stated definitely. The incidence of gastrojejunal ulceration is therefore appreciably higher than was shown in the statistics of Paterson.

When we inquire into the influence of the type of gastro-enterostomy on the site of the ulcer, we find that the character of the operation was mentioned in 130 instances. In 72 cases after anterior gastro-enterostomy, the ulceration was jejunal in 43 and gastrojejunal in 29. On the other hand, in 59 cases following posterior gastro-enterostomy, the ulceration was jejunal in 28 and gastrojejunal in 31. This may possibly be due to the fact that physiological conditions play a greater part in the production of true jejunal ulcers than of gastrojejunal ulceration, and that it is probable that these physiological conditions act more powerfully after the anterior than the posterior operation.

PATHOLOGICAL ANATOMY.

Two clinical types are met with: (1) The acute perforating ulcer; and (2) The chronic ulcer. As in the case of gastric and duodenal ulcers, these two types merge into each other, the acute ulcers tending to become chronic, while perforation is not unknown in the chronic cases.

1. *The acute jejunal ulcer* resembles the acute ulcer of the stomach, and has a punched-out, round appearance. It rapidly spreads through the thin jejunal wall and

produces perforation and peritonitis. This occurred in 21 out of 74 cases of anterior gastro-enterostomy (28·7 per cent), and in 10 out of 61 cases of posterior gastro-enterostomy (16·3 per cent), so that perforation is definitely a greater risk in jejunal ulcer following anterior gastro-enterostomy.

2. *The chronic ulcer* has shelving edges, and sets up local peritonitis over it, the ulcer becoming adherent to surrounding structures, and in many cases producing a large inflammatory swelling. The course taken by these chronic cases differs according to the type of the preliminary gastro-enterostomy.

When this has been of the anterior type, the ulcer tends to adhere to the anterior abdominal wall, usually behind the left upper rectus muscle, and a large tumour is produced in this situation ; a process of chronic perforation ensues, the ulcer gradually perforating the abdominal wall, and finally producing an external fistula (as in Paterson's case). In one case the ulcer penetrated into the liver. Only in rare cases does the ulceration burrow its way into the colon and produce a fistula into this viscus ; in 21 cases of jejuno-colic fistula the preliminary operation was of the anterior type in 2 only, and in one of these the operation was done by the retrocolic route, thus bringing the anastomosis into the same relation to the colon as in the posterior operation.

Chronic ulcer following posterior gastro-enterostomy also leads to an inflammatory swelling, but this is not so evident clinically, because it is hidden behind the colon and mesocolon. Chronic perforation of the true jejunal ulcer into the colon may occur, the colon becoming adherent to the base of the ulcer, and the ulceration then extending into the lumen of the large bowel. When the ulceration is on or near the anastomosis, it extends into the mesocolon, which becomes much thickened, and both contract, pulling the colon down to the anastomosis, to which it adheres, a fistula being formed in the usual manner.

In the process of healing, or partial healing, of these ulcers, contraction and stenosis may ensue. In the case of true jejunal ulcer there may be a stenosis of the affected portion of jejunum, usually the efferent limb, the afferent limb being dilated and hypertrophied. When the ulcer is situated in the jejunum opposite the stoma, contraction may produce a spur in the jejunal loop, and in this way obstruction of the gastro-enterostomy opening may follow ; such a condition is described by Edington and Moynihan.

By far the commonest form of stenosis, however, is that which results from gastro-jejunal ulceration, which leads to narrowing of the gastro-enterostomy opening. In some cases this may be so extreme as to lead to complete obliteration of the stoma, and there is no doubt that the cases of narrowing and obliteration of the opening which have been reported after gastro-enterostomy are due to antecedent ulceration, and not to non-functioning of the artificial opening owing to patency of the pylorus, as was at one time suggested. It is a noteworthy fact that narrowing of the gastro-enterostomy has been observed in many cases of true jejunal ulceration, and by some writers this has been considered a causal factor in the production of the jejunal ulcer. It seems more likely that in these cases the same causes which produced the jejunal ulceration had also set up ulceration on the anastomosis, to which the contraction was secondary.

ETIOLOGY.

The etiology of this grave condition is a matter of first importance, as it is only by a correct appreciation of the causes that we can hope to minimize or avoid it. Paterson estimates the incidence of jejunal ulceration at 1·5 per cent ; and while one may think this an over-estimate, and there are no figures which allow of an accurate estimate, there is no doubt that it is sufficiently frequent to be a serious drawback to an otherwise valuable operation.

Age.—This is of no importance. The youngest case was two months old (Mickulicz). The oldest was 81. The majority of cases occur between the ages of 30 and 45, as one would expect, this being the period of life at which gastro-enterostomy is most frequently performed.

Sex.—As regards sex, there is a marked preponderance in the male sex. In 140 cases of active ulceration in which the sex was mentioned, 113 were males and 27 females. While it is true that gastric and duodenal ulcers are commoner in men than in women, this relationship is even more marked in the case of jejunal ulceration. Thus, W. J. Mayo[1] had 154 gastric and duodenal ulcers in men to 46 in women. In dealing with duodenal ulcers alone, however, he had 83 men to 17 women, the proportion of males thus being even higher than in jejunal ulceration. It would seem that, even taking into consideration the greater frequency of operation for gastric and duodenal ulcer in males than females, the incidence of jejunal ulcer is rather greater in the former. Probably this is due to some physiological factor, as in the case of duodenal ulcer.

Type of Preliminary Operation.—When we study the cases of active ulceration, excluding the doubtful cases and the cases of simple stenosis without active ulceration, we get the following statistics as to the preliminary operation :—

Anterior gastro-enterostomy	38
Anterior gastro-enterostomy with entero-anastomosis ..	26
Anterior gastro-enterostomy en Y	10
Posterior gastro-enterostomy	54
Posterior gastro-enterostomy with entero-anastomosis ..	3
Posterior gastro-enterostomy en Y	5
Partial gastro-enterostomy	2
Not definitely stated	7

Thus, the preliminary operation was of the anterior type in 74 cases and the posterior type in 62; and when we consider that the posterior operation must have been done much more frequently than the anterior, it is evident that there is a greater liability to this complication after the anterior than the posterior operation. At first sight this inequality would appear to be greater than it really is, but further examination reveals the interesting fact that in a large proportion of the anterior cases—36 out of 74—the operation has been complicated by an entero-anastomosis or has been of the Y type. We shall see later on that this has an important bearing on the production of jejunal ulceration. Of the 62 posterior operations, only 8 were en Y or with entero-anastomosis. Jejunal ulcer, therefore, followed only 38 cases of uncomplicated anterior gastro-enterostomy, while in 54 cases it followed uncomplicated posterior gastro-enterostomy. It is, of course, impossible to estimate the relative number of anterior and posterior operations which have been performed to the present date; but the posterior operation must have been carried out much more frequently than the anterior, and the inference may be drawn that jejunal ulceration is commoner after anterior than posterior gastro-enterostomy, though possibly the noxious influence of the anterior operation has been overestimated in the past.

In 139 cases where the type of the preliminary operation is given, in 44 it was en Y or with entero-anastomosis. This is relatively a very high proportion, and well illustrates the influence of these proceedings on the production of jejunal ulceration. It is significant that no case of secondary ulceration has been reported after the operation of gastro-duodenostomy.

Exciting Causes.—When we come to consider the actual, as opposed to the predisposing, causes of jejunal ulceration, we find that they can be divided into two groups : (1) Physiological; (2) Errors in technique.

1. *Physiological.*—This group, in effect, means the action of the gastric juice on the mucous membrane of the anastomosis or of the jejunum, and it almost certainly has an effect in all the cases of ulceration, even when it is not the sole cause.

Paterson and other writers lay great stress on the effect of increased acidity of the gastric contents, maintaining that a high acidity injures the mucosa and allows the digestive action of the gastric juices to come into play. In a number of cases hyperacidity has been noted, and it seems likely that this condition increases the liability to ulceration, though the experimental work of Wilkie did not support this view. The hypothesis is further supported by the fact that only one case is reported as following operation for gastric carcinoma, and in that case there was probably a septic element, as the ulcers were

multiple and appeared within a short time of the operation. It is notorious that the acidity of the gastric contents is lowered in carcinoma, and therefore we would expect these cases to remain free from jejunal ulceration if this is caused by the action of the acid gastric contents. Further confirmation is found in the fact that after operations en Y and with entero-anastomosis we find a higher proportion of jejunal ulcer. After these operations the alkaline pancreatic and intestinal secretions are deviated from the anastomosis and a portion of the jejunum, and therefore unneutralized gastric contents come into contact with a mucous surface which is not accustomed to the action of an acid digestive fluid, and ulceration is easily set up.

On the other hand, there are records of cases of jejunal ulcer where the examination of the gastric contents has revealed no hyperacidity, and even diminished acidity. Probably, therefore, the action of the gastric contents depends on their digestive properties and not on hyperacidity, but the latter increases the activity of the former. This digestive action is brought into play by one or both of two factors : (*a*) The inability of the jejunal mucosa to withstand a digestive action to which it is unaccustomed ; (*b*) Local injuries of the mucosa.

a. The inability of the intestinal mucosa to withstand peptic digestion probably increases from the pylorus onwards, and this would explain the greater frequency of jejunal ulceration following the anterior operation. In this connection an interesting suggestion has been made by Dervaux—viz., that the lower we descend in the intestine, the less secretin is produced, and therefore the less secretion of pancreatic juice takes place. In other words, the chemical reflex producing the secretion of pancreatic juice is lessened in intensity, and this is more marked in cases of anterior than posterior gastro-enterostomy. The neutralization of the gastric contents is therefore less perfect in these cases, and the production of jejunal ulceration is favoured.

b. As we shall see later, errors of technique have more say in the production of gastro-jejunal ulceration than in the case of true jejunal ulcers ; and it is interesting to observe that, in 72 cases following anterior gastro-enterostomy, true jejunal ulcers were present in 43, gastrojejunal ulceration in 29 ; while in 59 cases after the posterior operation, true jejunal ulcers were seen in 28, and gastrojejunal ulceration in 31 ; showing the greater physiological liability to ulceration after the anterior than the posterior operation.

2. *Errors in Technique*.—These play an important part in the production of jejunal ulcers, and it is by a careful study of them that we may hope to lessen the incidence of the condition. Of prime importance is the method of effecting the anastomosis.

In 14 cases in my series this had been accomplished by means of a Murphy's button or bobbins. The Murphy's button produces a line of necrosis which must heal by granulation, giving a favourable opportunity for the gastric contents to act. Further, both buttons and bobbins are foreign bodies of a hard nature, which can easily injure the mucosa away from the suture line, allowing access of the gastric juices to the injured tissues.

The usual method of union is by a double row of continuous sutures, and for the most part an unabsorbable material such as silk, linen thread, or Pagenstecher thread has been employed. There is a gradually increasing body of opinion that it is the presence of such an unabsorbable suture that is the cause of secondary ulceration, particularly of the gastrojejunal type. The earliest instance in which this was observed was the case of Professor Berg (No. 62). Van Roojen also published a case (Berindina M.), but quotes the case of Battle (No. 13)—where a silk thread was present in the gastro-enterostomy opening, while the ulcer was 1½ in. below—as proving that such a thread may be harmless. We shall see shortly how this may be explained differently. In my list I have records of 13 cases in which the silk suture undoubtedly played an important part in the production of the ulceration (Nos. 13, 48, 62, 100, 107, 111, 112, 113, 115, 116, 117, 120, 121) ; and it is noteworthy that, since attention has been directed to this point, the condition has been reported with increasing frequency.

The harmful effects of the unabsorbable continuous suture may be produced in various ways. An infected suture may produce ulceration on the anastomosis, primarily of an acute infective character, which later on becomes chronic owing to the digestive action

of the gastric contents. Again, a sterile suture may, as it becomes loosened, tear out of the anastomotic ring, and produce a lesion which allows the digestive action to commence. In either of these two ways gastrojejunal ulceration may be set up. True jejunal ulcer may also arise as the result of the presence of such a suture. In my own case (No. 120), the ulcer was about half an inch beyond the anastomosis, and undoubtedly arose from the injury inflicted on the mucosa by the knot of the silk suture which was becoming loosened. The passage of the stomach contents waves the loosened suture about and rubs it against the jejunal mucosa, abrading this and leading to ulceration. It is not difficult to imagine a similar process occurring somewhat further down the jejunum, when the stitch has become almost entirely free, but is still attached at the lower angle of the gastro-enterostomy opening. This theory is in accordance with the usual situation of jejunal ulcers in the efferent loop, as the flow of the gastric contents would naturally carry the thread in this direction. It is quite easy to see that this may have been the origin of the ulceration in many cases where no suture has been found at the secondary operation, because the cases are not usually operated on until some considerable time has elapsed after the onset of the ulceration, and in the meantime the suture may have finally broken loose and disappeared.

When the harmful effects of the continuous unabsorbable suture were first recognized, it was thought to overcome this by the use of catgut for the inner layer of sutures. This is not sufficient to prevent jejunal ulceration, as is shown by the case reported by Barling (No. 145), where catgut was used for the inner layer and thread for the outer layer. It is proved by various observations that the outer layer of suture material can work its way into the lumen of the intestinal canal. Thus, in Wilkie's experiments, in his sixth series a posterior no-loop gastro-enterostomy was done, using catgut for the inner layer and silk for the outer. The animal was fed on hard meat and acid (through a stomach tube), and killed on the seventh day. There was a gastrojejunal ulcer with the silk outer suture projecting from it. A very important case also was reported by Woolsey,[2] where posterior gastro-enterostomy was done for duodenal ulcer, catgut being used for the inner layer and thread for the outer layer of sutures. Symptoms recurred one year and eight months later, and a second operation was undertaken two years after the primary one, when no ulceration was found, but the linen thread was seen hanging in loops inside the gastro-enterostomy opening. Removal of this thread cured the symptoms. In my own case also (No. 120), at the last operation no more silk was encountered, though two rows of silk were used for the anastomosis, the presumption being that the inner layer of sutures had been shed harmlessly, and that the outer layer was the one producing the ulceration. Pool,[3] again, reports two cases where posterior gastro-enterostomy was done, catgut being used for the inner and linen thread for the outer layer. Both were operated on six months after the primary operation, and in each case an ulcer was present on the jejunal side of the anastomosis, with thread in the bottom of the ulcer, in one case a knot lying there.

It is quite consistent with this theory that the ulceration may not appear for several years after the preliminary gastro-enterostomy. So long as the unabsorbable suture is *in situ*, it is a potential cause of harm. In fact, it probably is when it begins to loosen and be cast off that the mischief arises. Records are not wanting to show that such a suture may remain for several years. Thus, Delbet[4] mentions a case of pylorectomy with posterior gastro-enterostomy where a silk suture was passed three years after operation. Ricard[5] mentions a case of silk in a gastro-enterostomy one year after operation. In the case of Woolsey referred to above, the thread was still present two years after operation.

Various other errors in technique have been suggested as playing a part in the production of jejunal ulcer. Mayo records a case (No. 108) where a hæmatoma in the mesocolon produced by a needle prick was followed by a jejunal ulcer close to the anastomosis. The ulcer penetrated the whole thickness of the jejunum, the base being formed by the mesocolon, which was adherent at the site of the old hæmatoma. While it is difficult to see how a hæmatoma external to the bowel could lead to ulceration inside,

one could readily imagine that extravasation between the mucosa and muscular coats of the stomach and jejunum might lead to ulceration. This condition occurs when the hæmostatic stitch is not efficient, and also in cases where the inner layer of sutures is taken through the mucosa only.

The pressure of clamps has been suggested as a cause, but there is no evidence in support of this, and the same may be said of the theory of diminished blood-supply due to arteriosclerosis or to kinking of blood-vessels.

In a few cases an acute septic infection is probably present—viz., where the ulcers are multiple ; and it is noteworthy that in the few recorded cases of this type the onset of the ulceration has been rapid.

Delayed healing of the anastomosis, and consequent ulceration, may sometimes be due to injudicious feeding of the patient in the early days of the operation. The experiments of Wilkie support this view.

I would summarize my views on the causation of jejunal ulcer as follows :—

1. Jejunal ulcer is due to the digestive action of non-inactivated or imperfectly inactivated gastric contents on a mucosa which is not accustomed to withstand gastric digestion.

2. Such digestive action is more powerful when hyperacidity is present.

3. The lower in the intestine we go, the more powerful is the noxious influence of the gastric contents.

4. To enable the gastric digestion to come into play, some local injury of the mucosa is for the most part necessary. In the great majority of cases this is produced by the presence of a continuous unabsorbable suture, or by the presence of Murphy's button or some kind of bobbin.

5. In a few instances ulceration may occur as the result of the action of gastric contents without the help of any local injury. This is supported by the fact that jejunal ulcer can appear independently of gastro-enterostomy, as described by Schmilinsky.[6]

CLINICAL PICTURE.

The clinical picture in these cases varies according to the stage of the ulcer and the type of the original gastro-enterostomy.

Pain is the commonest symptom of all, and is present in nearly every case, the only exceptions being a few cases of perforation which have come on without any preliminary symptoms. The pain varies in character, sometimes suggesting a recurrence of the original ulcer after operation for duodenal ulcer, but it is noteworthy that in many instances the pain has no relation to the ingestion of food. Sometimes it is undoubtedly due to adhesions of the ulcer to the anterior abdominal wall. This was so in *Case* 1 (No. 120). Here the pain could always be brought on by the patient lying on the right side, a position which dragged on the adhesion of the ulcer to the abdominal wall. Where the original operation has been of the posterior type, adhesions to the posterior abdominal wall may be set up, in which case the pain will strike through to the back.

Vomiting is not common unless obstruction be present, either from stenosis of the stoma, spur formation in the jejunal loop, or annular stenosis of the jejunum.

Hæmatemesis and *melæna* are rare, but have been noted on several occasions. Acid risings and heartburn are not uncommon.

Local tenderness is usually present, and as a rule the tender spot is under the left upper rectus muscle. This tender spot may be quite definitely localized, or, where much tumour formation has occurred, it may be more diffuse.

Rigidity corresponding to the tenderness is usually found.

A local swelling can usually be detected under the left upper rectus muscle in cases following anterior gastro-enterostomy. Such a swelling is more difficult to feel after the posterior operation, even though considerable tumour formation exists.

When a fistula into the colon becomes established, a very definite train of symptoms follows. There is rapid and extreme emaciation, diarrhœa of the lienteric type, with

urgency of defæcation. Vomiting is present in a large proportion of cases, and the vomit is foul-smelling and contains fæces. Should there be no vomiting, there will probably be eructations of foul-smelling gas. The diagnosis can be confirmed by the recovery of fæcal matter from the gastric lavage and by radiographic examination.

Perforation leads to the usual symptoms of that condition.

TREATMENT.

The treatment of jejunal and gastrojejunal ulceration falls under two headings: (1) *Preventive*; and (2) *Curative*.

1. **Preventive.**—Under this heading come the technique of the preliminary gastro-enterostomy and the after-treatment of the patient. Needless to say, scrupulous care in aseptic technique is necessary to avoid any element of sepsis, and in cases where stenosis is present it is important to secure as clean an operative field as possible by a course of gastric lavage and by preliminary attention to the mouth and teeth. Gentle handling of the parts during the anastomosis, care in the application of clamps, and careful application of the inner hæmostatic stitch are all of the first importance; this stitch should be through all the coats, and not merely take the mucosa. Care should also be taken to avoid any tension on the mucosa, and for this reason I think the plan of excising mucous membrane is a mistake.

The anastomosis should always be by suture, and never by means of Murphy's button or bobbins. The suture material should be absorbable for both layers if a continuous stitch is employed. The Mayos use a continuous catgut stitch as the hæmostatic suture, and interrupted silk stitches for the outer layer, and in this way lessen the risk of jejunal ulceration. Since my case occurred, I have used continuous catgut sutures for both layers, using No. 0 catgut hardened in formalin and sterilized by the watery iodine method. At first I thought there was a risk of the catgut being absorbed too quickly and the anastomosis giving way, but I have now used this method in many cases without any trouble. Gronnerud[7] successfully used No. 1 pyoktanin catgut exclusively in 140 gastro-enterostomies, so we may consider that catgut may be relied upon to hold sufficiently long.

In closing the hole in the mesocolon after posterior gastro-enterostomy, the meso-colon should be sutured to the stomach well away from the line of the anastomosis, as recommended by the Mayo brothers. Should the patient be so unfortunate as to develop a jejunal ulcer afterwards, it will then be much more accessible.

In the after-treatment of these patients we should beware of allowing solid food too early. Wilkie's experiments showed clearly the evil effects of the trauma of lumps of meat on the healing gastro-enterostomy opening. At least a week should elapse before solid food is given, in order to allow the opening time to heal. It is important also, as Paterson has pointed out, to insist on care in the diet of these patients for a long time after operation, and to take steps to treat any increased acidity should such be present.

As regards the choice of operation, everything is in favour of the modern no-loop gastro-enterostomy with a wide opening. Theoretically, gastroduodenostomy is to be preferred, as no case of secondary ulceration has been reported thereafter. Practically, however, this operation has its dangers, especially the serious one of acute dilatation of the stomach. Gastro-enterostomy en Y and with entero-anastomosis should be avoided, the clinical evidence being strongly in favour of the influence of these operations on the production of secondary ulceration.

2. **Curative.**—When secondary ulceration has appeared, the question of treatment by medical or surgical means arises. Paterson advises a preliminary course of medical treatment—by rest in bed, rigid dieting, and the administration of alkalies—in the hope that this may cure the ulcer, or, failing that, may reduce hyperacidity and give surgical measures a better chance of success. This should be done as soon as any pain appears; but such a course of treatment should not be persisted in for any length of time, as there is no doubt that surgical treatment is infinitely easier in the early stages before extensive adhesions have formed.

It is true that in the series of published cases secondary operation has had only a very moderate success, and has in some cases failed dismally. In very many cases also more than one intervention has been necessary before a successful result has been obtained. Thus, in 145 proved cases, 19 died without any operation being performed; in 93 only one intervention was made; while in 26 two, in 5 three, and in 2 four interventions were necessary. When we study the end-results we find the following: deaths, 38; no relief, or incomplete relief, 25; well at the time of the report, 82. The number of cases reported cured is probably exaggerated, as many of the reports are dated a few months after the operation.

The results of surgical treatment so far can only be regarded as unsatisfactory, and it is probable that this is so because the etiology of the condition is not fully understood. It is a remarkable fact that many of the secondary operations have resulted in a gastro-enterostomy en Y or with entero-anastomosis, types of operation in which secondary ulceration is especially prone to happen. Further, we find that Murphy's button has been used occasionally in a secondary operation, and probably silk or thread sutures have been invariably used. I regard the use of absorbable catgut sutures as a matter of the first importance in any secondary operation which is undertaken.

Where the preliminary operation has been an anterior gastro-enterostomy, with or without an entero-anastomosis, the gastro-enterostomy opening should be undone—the opening in the stomach being closed in the usual way, and the small intestine being restored or closed as may be indicated. When pyloric stenosis is present, a large no-loop posterior gastro-enterostomy opening should then be made, *catgut alone being employed for the anastomosis*. If the pylorus is patent, and the original lesion cured, we are faced by a more difficult problem, but here again the gastro-enterostomy should be undone. This will often necessitate resection of a portion of the bowel and of the stomach wall. The opening in the stomach should be closed as usual. If possible, the opening in the jejunum should be sutured transversely. If this is not possible, the upper end of the bowel should be implanted into the side of the lower, the cut end of this portion of intestine being closed as a blind end, or, if possible, end-to-end anastomosis may be done. We are still left with the problem of dealing with the original lesion, usually pyloric stenosis. This should be treated by gastroduodenostomy or Finney's operation, whichever may be more convenient. If the original lesion was a duodenal ulcer, and there is no stenosis, it is better to excise the ulcer and allow the food to pass the natural way. In some cases the local conditions may render gastroduodenostomy or Finney's operation very difficult. Should this be so, it is probably better to make a new anterior gastro-enterostomy, using catgut only, than to trust to a new posterior gastro-enterostomy of the Y type. In all cases care in diet should be insisted on for a prolonged period, and any symptoms of hyperacidity should be treated by rest, careful dieting, and alkalies.

LIST OF REPORTED CASES.

In the following list, all of the cases, with the exception of those marked with an asterisk (), have been traced to the original references. The exceptions are those in which I was unable to obtain the original publications. They are, however, published in detail in several previous compilations of cases.*

A.—Where the Ulcer has perforated into the Peritoneal Cavity.

1 Braun, *Verhand. d. deutsch. Gesellsch. f. Chir.*, 1899, 94.
2 Hahn, *Ibid.*, 74.
3 Korte, *Ibid.*, 1900, 137.
4 Steinthal, *Ibid.*, 139.
5, 6 Goepel, *Ibid.*, 1902, 108.
7 Goepel, see Tiegel, *Mitteil. a. d. Grenzgeb. d. Med. u. Chir.*, 1904, xiii, 914.
8 Mickulicz, *Ibid.*, 897.
9 Edington, *Glasgow Med. Jour.*, 1907, June, 463.
10 Hall, see Paterson, *Ann. Surg.*, 1909, l, 379.
11 Rushton Parker, see Paterson, *loc. cit.*
*12 Hamann, *Cleveland Med. Jour.*, 1907, May, 183.
13, 14 Battle, *Lancet*, 1906, xi, 274 and 1246.
15 Graser, *Verhand. d. deutsch. Gesellsch. f. Chir.*, 1906, i, 95.

16 Hybrinette, see Einar Key, *Nord. med. Archiv.*, 1907, xl, Afd. i.
17 Lennander, see Einar Key, *loc. cit.*
*18 Cackovic, *Liecnicki Viestnik*, 1903, vii.
19 Delaloye, *Deut. Zeit. f. Chir.*, 1906, 518.
20 Brentano, *Centralbl. f. Chir.*, 1903, vii, 203.
21, 22 Eiselsberg, *Ibid.*, 1910, 1532.
23 Petrén (Bärrhjelm), *Beitrag. z. klin. Chir.*, 1911, lxxvi, 305.
24 Petrén (Euren), *Ibid.*
25 Jensen, see Zuleger, *Zur Kasuistik des Ulc. pept. Jejuni nach Gastro-enterostomie*, Dissert., Leipzig, 1909.
26 Dudgeon and Sargent, after Connell, *Surg. Gyn. and Obst.*, 1908, No. 1.
27 Maylard, *Lancet*, 1910, Feb., 497.
28 Hitzrot, *Ann. Surg.*, 1911, i, 571.
29 Marquis (Hartmann), *Bull. et Mém. de la Soc. de Chir.*, 1913, Dec. 2, 1517.
30 Rowlands, *Guy's Hosp. Gaz.*, 1913, April, 149.
31 Norman Point, see Moynihan, *Med. Rec.* i, 11.
32 Paterson, H. J., *Ann. Surg.*, 1909, l.

B.—Cases in which a Local Tumour has resulted.

33–36 Mickulicz, see Tiegel, *Mitteil. a. d. Grenzgeb. d. Med. u. Chir.*, xiii, 897.
37 Brodnitz, *Verhand. d. deutsch. Gesellsch. f. Chir.*, 1903, 77 and 1906.
*38, 39 Cackovic, *Liecnicki Viestnik*, No. 7.
40 Neuman, *Deut. Zeit. f. Chir.*, lviii, 270.
41 Kocher, *Verhand. d. deutsch. Gesellsch. f. Chir.*, 1902, 103.
42 Heidenhain, *Ibid.*, 108.
43 Quénu, *Bull. et Mém. de la Soc. de Chir.*, 1902, xxviii, 250, and 1904, xxx, 194.
44, 45 Czerny, *Beitrag. f. klin. Chir.*, xxxix, 99, and Supplement, 98.
46–49 Rotgans, see Van Roojen, *Archiv. f. klin. Chir.*, xci.
50 Rombouts, *Ibid.*
51 Oidtmann, *Ibid.*
52 Herczel, *Ibid.*
53 Akerman, *Ibid.*
54 Mayo Robson, *Trans. Roy. Med. and Chir. Soc.*, lxxxvii, 339, and *Ann. Surg.*, 1904, 90.
55 Jahr, *Berlin klin. Woch.* 1905, xliva, 100.
56, 57 Kronlein, see Schostak, *Beitrag. z. klin. Chir.*, lvi, 360, 366.
58 Fritzsche, *Ibid.*, 368.
59 Lanz, see Wullstein and Wilms, *Lehrbuch d. Chir.*, 3 Auflg.
60 Hildebrand, see Bosse, *Centralbl. f. Chir.*, 1907, 192.
61–64 Berg, see Einar Key, *Nord. med. Archiv.*, 1907, xl, Afd. i.
65 Kronlein, *Verhand. d. deutsch. Gesellsch. f. Chir.*, 1902, 110.
*66, 67 Rotgans, see Vachez, *L'Ulcère Peptique du Jéjunum*, Thèse de Paris, 1907.
*68 Monprofit, *Ibid.*
69 Karström, see Petrén, *Beitrag. z. klin. Chir.*, lxxvi.
70 Berg, *Ibid.*
71, 72 Key, *Ibid.*
73 Hellström, *Ibid.*
74 Borelius, *Ibid.*
75, 76 Paterson, H. J., *Ann. Surg.*, 1909, l, 368.
77 Von Hacker, see Hofman, *Beitrag. z. klin. Chir.*, 1906, l, 736.
*78 Zuleger, *Zur Kasuistik des Ulc. pept. Jejuni nach Gastro-enterostomie*, Dissert., Leipzig, 1909.
*79 Jensen, see Zuleger, *loc. cit.*
80–88 Schwarz, *Archiv. f. klin. Chir.*, 1914, civ, 694.
89–93 Haberer, *Ibid.*, 1913, ci, 669.
94 Dervaux, *Archiv. Provin. de Chir.*, 1913, xxii, No. 9.
95 Flörcken, *Centralbl. f. Chir.*, 1914, No. 7, 281.
96 Schloffer, *Beitrag. z. klin. Chir.*, xxxii, Heft. 2, 357.
97 Hofman, *Ibid.*, l, 742.
98 Von Eiselsberg, *Centralbl. f. Chir.*, 1910, 1532.
99 Borszéky, *Bruns. Beitrag. z. klin. Chir.*, lvii, 125.
100 Connell, *Surg. Gyn. and Obst.*, 1908, Jan., 39.
101–3 Wilkie, *Edin. Med. Jour.*, 1910, v, 316.
104 Lawen, *Münch. med. Woch.*, 1910, Jan., 102.
*105 Leriche, see Denouai, *Thèse de Lyon*, 1908–1909, No. 97.
106–108 Mayo, W. J., *Surg. Gyn. and Obst.*, 1910, March, 227.
109 Navarro, see Hartman, *Bull. et Mém. de la Soc. de Chir.*, 1910, 1092.
110 Marquis, *Ibid.*, 1913, 1517.
111 Ricard, *Ibid.*, 1536.
112 Soresi, *Ann. Surg.*, 1915, lxi, 328.
113 Pearson, *Trans. of Roy. Soc. of Med. of Ireland*, 1912, xxx, 193.
114 Rowlands, *Guy's Hosp. Gaz.*, 1913, April, 149.
115, 116 Pool, *Ann. Surg.*, 1917, July, 122.
117–119 Moynihan, *Universal Med. Rec.*, i, 11.
120–122 Garnett Wright, *Brit. Jour. Surg.*, 1919, vi, 390.

C.—Cases with Fistula Formation into Colon.

123 Czerny, *Beitrag. z. klin. Chir.*, xxxix, 99.
124 Kaufman, *Mitteil. a. d. Grenzgeb. d. Med. u. Chir.*, 1906, xv, 151.

*125 Spassokukozki, S. J., *Russki Wratsch.*, 1909, No 49.
126 Pinner, *Berlin. klin. Woch.*, 1912, Sept. 23, 1837.
127 Gosset, *Rev. de Chir.*, 1906, xxxiii, 59.
*128 Florschütz, *Liecnicki Viestnik*, 1909, No. 5.
129 Van Stockum, see van Roojen, *Archiv. f. klin. Chir.*, cxi.
130 Koch, *Ibid.*
131 Rotgans, *Ibid.*
132, 133 Herczel, *Ibid.*
134, 135 Von Eiselsberg, *Centralbl. f. Chir.*, 1910, 1532.
136 Nélaton, see Lion and Moreau, *Rev. de Chir.*, 1909, xxxix, 873.
137 Gosset, *Ibid.*
138 Port and Reizenstein, *Mitteil. a. d. Grenzgeb. d. med. u. Chir.*, 1907, xvii, 590.
*139 Sesin, *Wratsch. Gaz.*, 1909, Nos. 9 and 10.
140 Polya, *Deut. Zeit. f. Chir.*, 1913, cxxi, 101.
141 Schwarz, *Archiv. f. klin. Chir.*, 1914, civ, 694.
*142 Vautrin, *Rev. Méd. de l'Est*, 1909, 680.
*143,144 Ramonéde, see Urrutia, *Archiv. de l'Appareil Digestif*, 1912, vi, 33.
145 Barling, *Brit. Jour. Surg.*, v, 343.

D.—Cases of Simple Stenosis of the Stoma.

146 Kehr, *Münch. med. Woch.*, 1899.
147 Korte, *Deut. med. Woch.*, 1901.
148 Gelpke, *Archiv. f. klin. Chir.*, lxxx.
149–154 Kramer, *Bruns. Beitrag. z. klin. Chir.*, li.
155 Finney, *Ann. Surg.*, 1914, lx, 131.

E.—Probable, but not proven, cases of Jejunal Ulcer.

156 Rubritius, *Beitrag. z. klin. Chir.*, lxvii.
157 Lyle, *New York Med. Jour.*, 1906, 1230.
158 Paterson, *Brit. Med. Jour.*, 1909, 2525.
159 Kramer, *Beitrag. z. klin. Chir.*, li, 320.
160 Van Stockum, see van Roojen, *Archiv. f. klin. Chir.*, xci.
161, 162 Korteweg, *Ibid.*
163 Hadra, *Verhand. d. deutsch. Gesellsch. f. Chir.*, 1900, 152.
164 Fraenkel, *Deutsch. Archiv. f. klin. Med.*, 1905, lxxxiv, 217.
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SOME PHENOMENA OF SURGICAL SHOCK.

By A. RENDLE SHORT, Bristol.

The writer was privileged during the summer and autumn of 1917 to take a part in some investigations on surgical shock and allied conditions at a group of casualty clearing stations in France, and the substance of the present communication is composed of data then obtained. It is very difficult to give proper credit to all to whom credit is due in such a report, because so many of one's colleagues have contributed in a greater or lesser degree, but I have tried to indicate some at least of those whose interest was most active. The opportunity to carry out the investigation was provided by Colonel H. M. W. Gray, to whose kindness and co-operation we were continually indebted.

What is Surgical Shock?—Many patients who arrive at a casualty clearing station severely wounded are, to use the simplest of all descriptions, 'very bad,' and some would use the term 'shock' to indicate this condition of depressed vitality whatever its cause. It seems more useful in practice, and more in accordance with the traditional nomenclature of surgery, to reserve the term for depressed vitality due to traumatism, not including concussion or hæmorrhage. We have therefore to exclude the following factors making for depressed vitality or 'bad'-ness, before concluding that surgical shock is present :—

1. *Considerable Loss of Blood.*—Loss up to a pint does not by itself harm a healthy man, as all of us well know who have been in the habit of taking blood from donors for transfusion.

2. *Concussion*—of brain, spinal cord, or thorax.

3. *Toxæmia from Intestinal Paralysis.*—I am convinced that much which passes for delayed or secondary shock is due to this cause.

4. *Syncope from Mental Effects*, such as sudden pain or emotion. This is a very transient phenomenon.

5. *Toxæmia from Acute Streptococcal Infection or Incipient Gas Gangrene.*—This, again, is a very potent factor, often confused with shock, and accounting for the great majority of cases of 'delayed shock.' It may come on within twenty-four or forty-eight hours of wounding, or, rarely, in eight hours.

It may be doubted at first, when all these deductions have been made, whether any such condition as surgical shock remains to be considered. Admittedly, in war surgery, several factors are usually at work. But there is a residuum. Part of the 'bad'-ness is due to the damaging of tissues. This is shock. It is seen in its purest form in such instances as the following : Gunshot wound of the abdomen, with bad pulse and patient very ill, wound under twenty-four hours (after that period toxæmia takes the larger share in killing the patient) ; crushed chest ; death from amputation at the hip-joint. Big multiple injuries, such as gunshot wounds of both femurs, introduce a lot of shock, with some syncope at first, hæmorrhage later, and toxæmia from infection after a day or two. In ordinary, a patient with a big smash is much worse than one who has lost the same amount of blood from a small clean wound involving an artery, even before toxæmia comes in to complicate the picture.

Phenomena of Surgical Shock.—The well-known signs such as pallor, loss of muscular power and tone, some blunting of the mind, quick weak pulse, fall of blood-pressure, subnormal temperature, reduced urine, etc., need merely be mentioned. We frequently tested the knee-jerks. They are usually normal ; in deep shock they may be lost.

It is probable that shock may be present before the blood-pressure falls, though it is difficult to recognize it, except that the patient 'looks bad.' This is important, because

we all know how frequently a man is sent off the operating table with a good pulse, but already with his life in grave danger, and a few hours later he suddenly becomes ill and dies.

On the other hand, a fall of blood-pressure does not necessarily prove shock. Turning a patient with gunshot wound of the abdomen after the laparotomy, to excise a wound of the back, may cause a fall of blood-pressure ; but this is quite probably due to syncope, and the patient may quickly recover.

In a small number of instances Captain C. E. Dukes or the writer took readings of diastolic as well as systolic pressure in cases of severe injury with or without signs of shock ; but the double reading did not teach us more than the systolic only.

Metabolism in Shock.—It has been abundantly proved by American workers, using Van Slyke's apparatus, that the alkali reserve of the blood is reduced in shock. There is, in other words, a condition of acidosis (although the terms are not exactly synonymous). Captain C. E. Dukes and I made an investigation of this phenomenon by estimating the ammonia nitrogen in the urine, and found in six cases a constant rise ranging from 13 to 23 per cent (normal is 3 per cent) when shock was present. In two patients who seemed bad, but had normal blood-pressures, the ammonia nitrogen was also normal. It is well known, of course, that the ammonia nitrogen excretion is a simple indirect measure of the H-ion concentration of the blood. In one case, as shock deepened, the acidosis rose from 14·6 to 23 per cent in sixteen hours.

What is the nature of the excreted acid ? It is not β-oxybutyric or diacetic acid ; we never obtained red coloration with ferric chloride even after oxidizing with hydrogen peroxide (to oxidize β-oxybutyric to diacetic acid). It is not lactic acid ; it is true that the urine both of shocked and normal persons may give a yellow colour with Uffelmann's reagent (due to phosphates) ; but when the urine of a shocked patient is evaporated to dryness and the residue extracted with ether, the evaporated ether extract gives none of the reactions of lactic acid. It is probable that the excess of ammonia is carried out by amino-acids. This suggestion was first made to me by Sergeant Howard, of the —th Mobile Laboratory.

Whether the acidosis of shock is cause or effect of the exhaustion symptoms is another and more difficult question. We were in the habit of giving the cases alkaline drinks (citrates are preferable to carbonates, as they do not interfere with the gastric hydrochloric acid). General opinion seems to be that alkaline transfusion is no better in the treatment of shock than normal saline, and therefore it is probable that the acidosis is an accessory, not an essential, factor in the production of the exhaustion symptoms, especially as it follows and does not precede the fall in blood-pressure.

The Suprarenals in Shock.—For my Hunterian Lecture in 1914 I had measured the adrenalin content of suprarenals obtained by autopsy from persons dying of shock and of various other conditions, by determining the dilution necessary to induce contraction in a spiral strip of rabbit's aorta. I could not demonstrate that the adrenalin content of the gland was at all reduced. I repeated the observation on two cases dying of wound shock, and with the same result.

Toxicity of the Blood.—Captain Lindsay performed for me the following experiment : Ten c.c. of blood were taken from the heart blood of a man suffering from severe shock due to gunshot wounds of the abdomen, chest, both legs, and back (no visceral injury, but retroperitoneal hæmatoma), who died thirty-six hours after being wounded, the autopsy taking place within a few hours of death. This heart blood was injected into the ear vein of a rabbit. The rabbit was kept for several weeks, and exhibited no symptoms, except perhaps a transient drowsiness. Ten c.c. is a large dose for a rabbit, and this observation would seem to show that the blood in shock is not always toxic. The experiment was only done on one occasion.

It may be remembered that Professor Crile demonstrated in two dogs with the circulation artificially crossed that the signs of shock were only produced in the dog subjected to traumatism. Roger has shown that the blood of a shocked rabbit is not toxic to another rabbit.

The Blood-vessels in Shock.—The ancient controversy as to whether the arteries are dilated or contracted in surgical shock may now be taken as definitely settled—they are contracted. Indeed, there was never any evidence to the contrary. Dilatation of the arteries was a supposition following upon the theory that the pathology of shock was an exhaustion of the vasomotor centre.

The superficial veins are contracted, and often in a state of active spasm. On quite a number of occasions this has been very forcibly impressed upon us by the extreme difficulty in getting blood to enter the median basilic or median cephalic vein during blood transfusion. There was no doubt that the cannula was correctly placed. In some cases the blood could be seen distending the vein for an inch or two up. We have several times been compelled to leave the arm veins and give the blood by the internal saphenous in the groin, and even that has been found in a state of extreme contraction. It is true that all these cases had bled severely ; but I believe some contraction of the arm veins is also present, in a less degree, in pure shock (e.g., in amputation at the hip-joint for tubercle in a wasted boy).

It has been theorized for years that the abdominal vessels are dilated in shock ; but in acute abdominal catastrophes and early cases of gunshot wound of the abdomen before the advent of peritonitis, I have never seen any noteworthy vasodilatation either of veins or arteries. It has also been theorized that the liver is greatly engorged ; but this is not found either at operation or post mortem.

The condition of the capillaries opens up some new and very interesting problems. Dr. Dale has shown that in histamine-poisoning in cats, the symptoms closely resemble those of surgical shock ; there is a fall of blood-pressure, yet the heart is working well, and the arteries are contracted. The crucial problem in shock has always been how to explain a fall in blood-pressure with a normal heart, contracted arteries, and unexhausted suprarenal glands. In poisoning by histamine and certain other substances (acetyl-choline and *minute* doses of adrenalin), one has a similar problem. Dale advances what seems to be satisfactory evidence that in poisoning by these drugs the capillaries are dilated though the arteries are contracted. He also points out that a few hours or days after section of the sciatic nerve in a cat, the pads of the foot on the operated side are paler (= capillary contraction), though that paw is *warmer* than the other, not only to the touch but also to exact measurement ; for if both paws are immersed in water in test-tubes, the water on the side of the denervated paw is warmed up more quickly than the other (= arterial dilatation with capillary contraction on the operated side). There is, of course, no theoretical difficulty in imagining that the endothelial cells of the capillaries may be capable of expansion and contraction like the pigment cells in a frog's skin. Moreover, what Dale interprets as capillaries might mean the smallest arterioles with a muscular coat. That a drug should constrict one part of an artery and not another cannot be excluded as improbable, in view of the known variation in action of adrenalin on the pulmonary artery in its different parts (Douglas Cow).

Now, is the fall of blood-pressure in shock, associated as it is with an active heart, contracted arteries and veins, and unexhausted suprarenals, due to capillary dilatation ? Cannon has published figures indicating that in shocked wounded soldiers there is a higher red blood corpuscle count in the capillaries than in the veins. Captain Lindsay, Captain Dukes, and others, made a few such counts when working with me, and only found this disparity in one case out of five. [A Thoma-Zeiss hæmocytometer was used. Some of the hæmocytometers at the front were very inaccurate.] If the capillaries in shock are dilated, one would expect the lips and conjunctivæ to be flushed instead of pale. It is to the lips that we look for the capillary flush in aortic regurgitation. It is quite possible, however, that the relaxation of muscular tone to which, in my Hunterian Lecture, I attributed considerable importance in the causation of the low blood-pressure, may allow of dilatation of the intramuscular capillaries.

The Blood Volume in Surgical Shock.—War surgery does not offer many good opportunities for studies of the total blood volume by estimation of the specific



FIG. 338.—NERVE CELLS FROM CASES OF FATAL SHOCK.

1, Nucleus of twelfth nerve: upper medulla. 2, Small-celled dorsal nucleus of vagus: upper medulla. 3, Nucleus ambiguus: upper medulla. 4, Anterior horn of spinal cord. 5, Clarke's column. 6, Nucleus gracilis. 7, Lenticular nucleus. 8, Inferior olive. 9, Substantia nigra. 10, Nucleus of third nerve. 11, Red nucleus. 12, Betz cell. 13, Superior vermis of cerebellum. 14, Postcentral cortex. 15, Optic thalamus.

gravity, red-cell counts, or direct measurement by the vital-red method, because so many of the cases are complicated by unmeasured hæmorrhage. In pre-war civil surgery I found no alteration of the specific gravity in eight cases, but a marked concentration in two patients with severe burns. Observations by the vital-red method on cases of pure shock are urgently needed.

The Central Nervous System in Patients Dead of Shock. I have had the opportunity of cutting sections of the various parts of the brain and spinal cord of three patients dead of shock. Particulars are given in the appended protocol. It will be observed that in one of them at any rate (the second), the loss of blood was measurable, because there was no external bleeding, and it was not more than one can take with impunity from a donor for blood transfusion ; so that it does not seem that cerebral anæmia will explain the changes found.

In the main, the findings may be summarized as follows : The nerve cells of the sympathetic ganglia and of the spinal cord show no changes. The sensory nuclei of the brain (gracile and cuneate nuclei, optic thalamus) show profound loss of Nissl granules, indicative of cell exhaustion. The motor nuclei (Betz cells of precentral cortex, motor nuclei of medulla and pons, lenticular nucleus) are normal. The Purkinje cells of the cerebellum, as Professor Crile has pointed out in all his writings, show considerable loss of Nissl granules in most cases. In one case the vagus nuclei had lost all its granules.

No one is more conscious than I am that research by this laborious method needs to be extended to many more cases and controls before these generalizations can be safely accepted ; but they appear to me to suggest that the violent nociceptive (painful, or, in an anæsthetized patient, potentially painful) impulses passing up to the brain wear out first the sensory nerve nuclei and then the great vital centres.

It is well known that similar changes can be induced in nerve cells by exhaustion, and that the normal appearance of the cells can be restored by sleep. Here we find the rationale for the sleep treatment of shock on which Professor Crile has rightly laid such stress.

PREVENTION AND TREATMENT OF SHOCK.

I do not propose to enter very fully into this subject, but to give a personal impression of measures in general use. In practice—in war surgery—it is nearly always the shock-hæmorrhage syndrome that one has to treat.

Fluids.—There is no doubt as to the value, slight but definite, of giving fluids. We used a hot alkaline drink (potassium citrate) to counteract acidosis. Tea or coffee is good. Saline per rectum and saline subcutaneously are often helpful up to a certain point ; but when it comes, as it often does, to a question whether to get the patient comfortable and asleep under morphia, or to worry him with rectal or subcutaneous saline, I prefer the sleep and morphia treatment as more merciful and, I think, more efficacious.

Warmth is of great value in the prevention, and some value in the cure, of shock. Many excellent methods of applying it are now well known.

Sleep is also of considerable value. To secure it one must try to get seclusion, quiet (fill the patient's ears with wool, if necessary), warmth, darkness, and, usually, morphia in adequate doses. I do not believe that any quantity of morphia will do a patient any harm if it does not first give him ease and quiet—with the very important proviso that it must be given in divided doses at hourly intervals ($\frac{1}{4}$-, $\frac{1}{3}$- or even $\frac{1}{2}$-grain doses in the worst cases), and that the patient's circumstances must be such that he really has a chance to sleep if the morphia inclines him to. It is not necessary, as Professor Crile advised, to repeat the dose every hour until the respirations are reduced to twelve a minute ; but I shall never forget a case of gunshot fracture of the femur under the care of Lieutenant-Colonel Dun. I saw the patient at 2 o'clock, after he had had repeated $\frac{1}{4}$-gr. doses since admission in a state of shock at 10.30 ; although he had received over

2 grains of morphia in four hours, he was awake, free from pain, his pupils were not contracted, and his pulse was better. He did well. At any rate, such a case convinced one that perhaps in this country we had been too timid in our use of this most valuable drug for patients in extreme pain.

Drugs.—Adrenalin is dangerous. Strychnine is certainly useless, and possibly dangerous, as Professor Crile and Mr. Lockhart Mummery long ago pointed out. Alcohol may give a little Dutch courage to patients with syncope who like it, but in shock it does nothing but harm, especially after ether or chloroform has been given, for in that case it has not even the brief stimulating effect that may precede the longer depression. Pituitary extract is given on a theory that shock is due to arterial dilatation; the theory is erroneous, and the drug is useless unless there is an element of intestinal paralysis in the case; for that condition it is our best remedy. Camphor is well spoken of by some; I do not use it, and cannot speak from experience. Digitalin is, I think, useful both on theoretical grounds and as a matter of experience. One is almost compelled to give some hypodermic remedy, to pacify patients, friends, and nurses. It does not appear to be universally known how common it is for patients' pulses to fail during the later stages of an operation, and then to improve greatly, quite apart from any drug treatment, during the stitching up and application of dressings. It is this phenomenon which has given a fictitious reputation to strychnine, pituitary, etc., in the treatment of shock during an operation.

Transfusion.—Saline given intravenously has a definite, though very small, value; it frequently tides the patient over a brief period, such as an operation; but in a few hours its value is all gone, and in the great majority of cases death is not averted, only postponed. I am told by colleagues who have used alkaline transfusion and gum, that this is no better than saline.

With regard to gum transfusion, advocated by Professor Bayliss, it is usually harmless, and if given *immediately* after a hæmorrhage it may be life-saving in animals; but it seems very doubtful, both experimentally and clinically, whether it is any use to give it several hours after. Moreover, one has a prejudice against leaving such an extraneous substance as gum in the circulation.

Blood Transfusion.—In my opinion—based on about 40 cases which were given blood, usually from 15 to 20 ounces, by my colleagues or myself—blood transfusion is far more effectual and lasting as a remedy for the shock-hæmorrhage syndrome than any of the other substances mentioned. At first we used direct transfusion from the radial artery of donor to the median basilic vein of patient. In two cases it did well; but in two others I am sure that very little blood passed. It is impossible to know how much one gives, and the veno-spasm of the recipient must often prevent his receiving a single drop.

The method we afterwards used was that described by Captain Robertson, and originally devised for us (with some minor differences) by Captain Lindsay. It was worked out first on rabbits. *Group IV* donors were always used after Captain Robertson had shown us how to test them out.

Whether blood transfusion is of the same value for pure shock is a more difficult question; but the results were quite encouraging in some cases in which the shock element was larger than the hæmorrhage.

The observations and suggestions embodied in this paper are fragmentary, and need further extension; but they are placed on record to give interested workers on this great and important subject some lines of approach which they may care to follow up. In civil practice cases of severe shock are so infrequent that future investigation may be difficult.

I have not attempted in this communication to deal with the voluminous recent literature, but have reserved that for an article in the forthcoming volume of the MEDICAL ANNUAL.

PROTOCOL OF OBSERVATIONS ON THE HISTOLOGY OF THE CENTRAL NERVOUS SYSTEM IN PATIENTS DEAD OF SHOCK.

Case 1.—Man. Fell from ladder. Fractured pelvis, fractured humerus, retroperitoneal hæmatoma. There was no external hæmorrhage. Died 2½ hours after injury.

Case 2.—Pte. C. Run over by a lorry. Admitted suffering from crushed chest, in extreme pain. No external wound. Died 24 hours after injury.

Autopsy showed pulping of the whole of the left lung, fracture of seventh and eighth ribs, and 1½ pints of blood in the pleura.

Case 3.—Pte. S. Gunshot wound of back, with fractured spine, wound entering the abdomen; also multiple wounds of legs. Had lost much blood. Died 4 hours after wounding.

Case 4 (Control case).—Pte. G. Injury of head, not penetrating skull. Died about 48 hours after injury, without recovering consciousness.

Changes in Nerve Cells.

Nucleus	Case 1	Case 2	Case 3	Case 4
Posterior root ganglion (left seventh dorsal)	—	Normal	—	—
Spinal cord, anterior horn	—	Normal	Normal	—
„ „ posterior horn	—	Normal	Normal	—
„ „ lateral horn	—	Normal	Normal	—
Precentral cortex (Betz)	—	Normal	Normal	Granules reduced
„ „ (other cells)	—	Granules deficient	Normal	Granules almost absent
Postcentral cortex ..	—	Granules only well-marked in half the cells	Granules deficient, some cells empty	—
Optic thalamus	—	All cells almost devoid of granules	Almost no granules	Almost no granules
Cerebellum (Purkinje) ..	Normal	Deficient in granules	Granules very deficient	Granules very deficient
Medulla gracile nucleus	No granules	No granules	Almost no granules	Some deficient, some normal
„ cuneate „ ..	No granules	No granules	Almost no granules	Some deficient, some normal
„ inferior olive ..	Mostly normal	Granules deficient	Granules deficient	Almost no granules
„ XIIth nucleus	Normal	Normal	Normal	Normal
„ Deiter's „ ..	Granules reduced	Normal	Rather reduced in granules	—
„ arcuate „ ..	—	Normal	—	—
„ nucleus lateralis	—	Normal	—	Granules deficient
„ „ ambiguus	—	No granules	Almost no granules	Normal
Pons, VIth nucleus ..	Normal	Normal	—	—
„ Deiter's „ ..	—	Normal	—	—
„ superior olive ..	—	Normal	—	—
„ nucleus pontis ..	—	Granules about half normal	—	—
Substantia nigra ..	—	—	Normal	—
IIIrd nucleus	—	—	Normal	—
Red „	—	—	Normal	—
Lenticular nucleus ..	—	—	Normal	—

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A NEW SYSTEM OF LOCALIZATION AND EXTRACTION OF FOREIGN BODIES IN THE BRAIN: A PRELIMINARY NOTE.

By Captain J. NEWBERY FERGUSSON, R.A.M.C. (T.C.)

About two years ago, as officer in charge of the *x*-ray department of a general hospital at a base, I had occasion to examine a series of gunshot wounds of the head. A retained missile was localized in a considerable number of the cases examined, and in some of these operation was performed for extraction. I was present at most of the operations, and gradually came to realize that the methods of extraction were far from ideal. It seemed almost waste of time to determine the exact situation of the foreign body in relation to surface landmarks, when the localization was applied, at operation, merely by visualizing the measurements. The use of a finger, too, as an exploring instrument, did nothing to dispel the idea that our operative methods were imperfect. It is true that in most cases the missile was extracted, but often at the sacrifice of a considerable amount of brain tissue.

Convinced of the necessity for improved technique, I devoted much thought to devising a system of extraction which would reduce the operative trauma. The idea of enabling the surgeon to take full advantage of an accurate *x*-ray localization, by substituting mechanical control of the extracting instrument for visualization and digital exploration, particularly appealed to me, and the following notes outline its ultimate development.

The difficulties and dangers of the ordinary methods of extraction can be summarized for the purposes of this paper in a few lines. In the absence of any instrumental guide, it is difficult, and often impossible, to make use of the *x*-ray localization with any degree of precision. The missile can seldom be seen, and exploration of the brain cannot be carried out with the same impunity as in many other parts of the body. Though the foreign body may be felt with a probe, it is nevertheless difficult to grasp, and considerable damage may be done before it is extracted. The practice of introducing the finger along the track makes the extraction easier; but this technique is dangerous, especially when the missile is deeply situated, because it causes mechanical trauma, and aids the spread of sepsis, partly by physical dissemination of organisms, but perhaps to a greater extent by opening up lymph spaces and thus generalizing a local infection. If this damage could be reduced to the minimum, it would seem just as reasonable a procedure to extract a foreign body from the brain as from any other part.

In devising the method presently to be described, the chief considerations I had in view were that it should enable the operator to apply the information conveyed by *x*-ray localization with the utmost precision, and should admit of extraction being performed with the minimum of avoidable damage, either along the track of entry or through a fresh wound in any more convenient situation. The accompanying photographs illustrate the apparatus which I have had made for this purpose.

It will facilitate comprehension of the underlying idea if I compare it with the artillery system of 'indirect fire,' to which it bears in some respects a close resemblance. Just as a gunner can hit a concealed target when its direction and range from the firing point have been ascertained, so by the use of this apparatus can the surgeon extract a foreign body from the brain after its direction and distance from the operation wound have been indirectly determined. The gun is represented in the apparatus by a tubular guide, held rigidly close to the wound, and aimed through it at the concealed foreign body in a manner to be described. A long, slender, cylindrical-stemmed forceps, capable of

sliding through the tubular guide without resistance, takes the place of the shell; and the distance at which it will be able to grasp the foreign body, when pushed into the brain along the guide, represents the range. The gunner 'lays' his gun by bringing his dial-sight to bear on an aiming-post, or some conspicuous object in the landscape; the surgeon also makes use of an 'aiming-post,' as will be explained later. Certain parts of the apparatus which enable the tubular forceps-guide to be manœuvred into position and

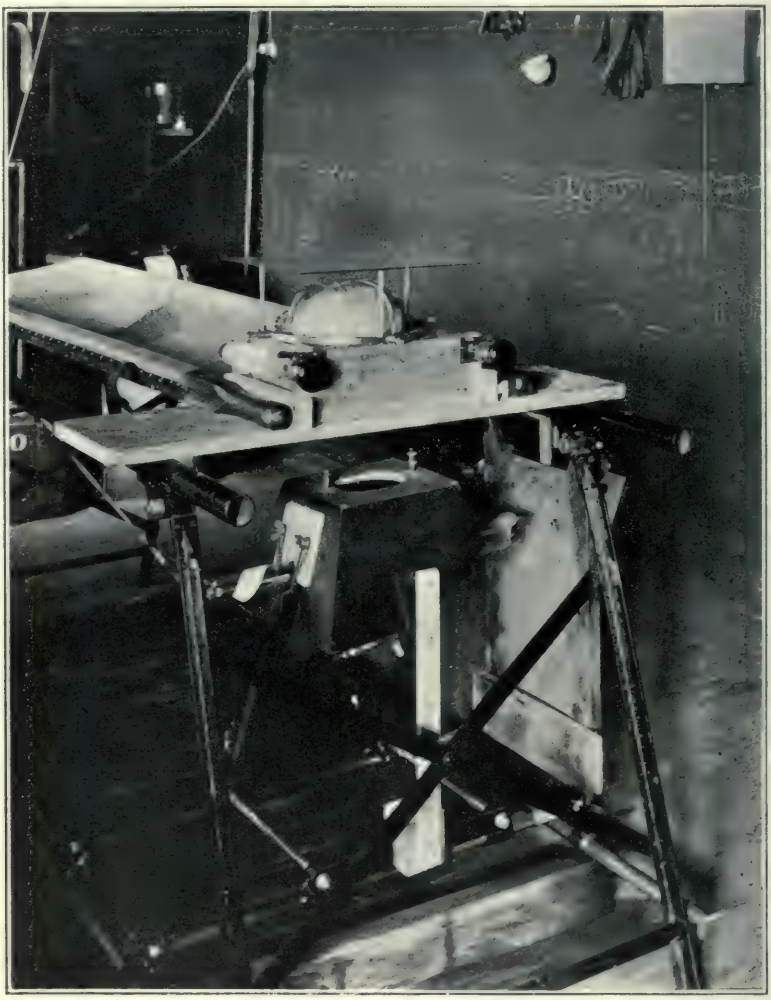


FIG. 339.—Method of obtaining double-exposure negative. The patient is so placed that the median plane of the head, with attached apparatus, lies horizontally, the weight of the head being borne by a head-rest consisting of a three-sided box across which hangs a canvas sling controlled at its ends by rollers. The head is lowered, after attachment of the apparatus, until the latter just touches the upper edge of the head-rest, in which position it is perfectly immobile. The *x*-ray plate lies above on three supports attached perpendicularly to the semicircle; the *x*-ray tube is below.

maintained there, may be compared with the mounting of the gun; while the steel semi-circle partly surrounding the skull, to which it is rigidly fastened, serves to support the whole apparatus, and may be said to correspond to the concrete platform on which the gun stands. The essential feature of the apparatus is that it enables the operator to direct a forceps of special design through the brain with such precision that the missile

is grasped and extracted without the use of any other instrument, or of a finger in the wound.

The apparatus consists essentially of a steel semicircle which can be fixed rigidly to

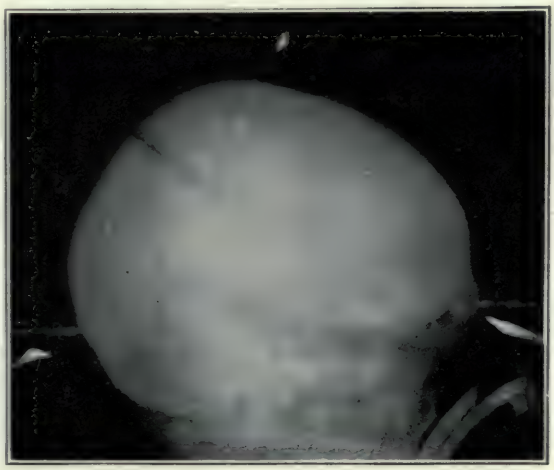


FIG. 340.—Double-exposure negative. The points of the plate-supports, having been in virtual contact with the plate, cast but one shadow each: the missile casts a double shadow. The skull appears as a blurred shadow, due to the overlapping of the two images: this is the explanation, also, of its apparent shortness. This negative belongs to *Case* 2.

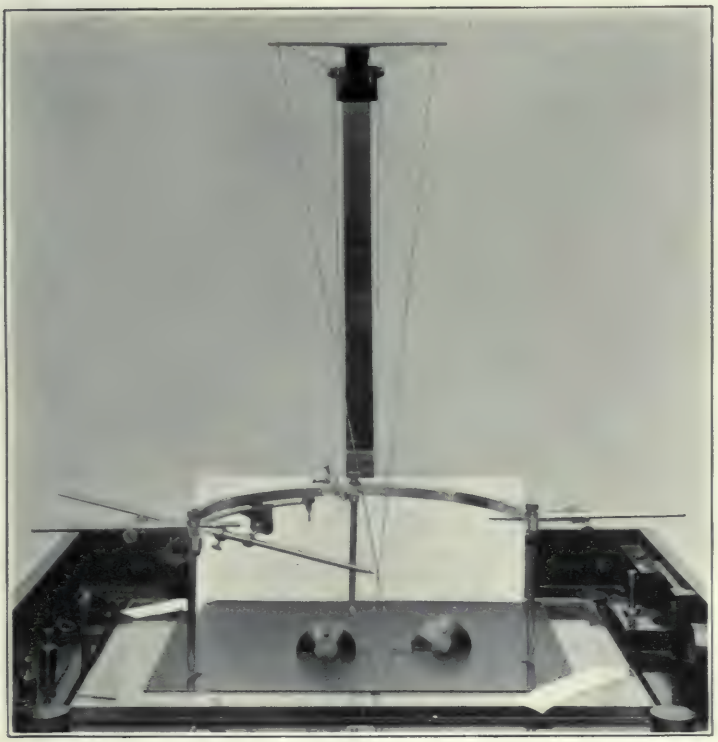


FIG. 341.—Localization by Mackenzie Davidson's cross-thread localizer. The apparatus stands on the negative in an inverted position, with the points of the plate-supports in correct register with their shadows. The points of suspension of the threads correspond with the positions of the focal point of the tube during the two exposures. The needles holding the lower ends of the threads rest on the shadows of the foreign body. The indicating probe has been set to mark the point of crossing of the threads, i.e., the position of the foreign body in relation to the apparatus.

the head in the sagittal plane by means of three pointed rods which fit into recesses drilled to receive them in the outer table of the skull. The provision of registering collars on the rods makes it possible to remove the apparatus from the head and restore it to

position without any error. Special instruments are used to make the holes in the outer table of the skull, the operation being effected through a 5-mm. incision. The incising and boring instruments are used through the sleeves which hold the fixing rods, thus ensuring that the holes shall be drilled in precisely the right places. It is then quite easy to 'feel' the points of the fixing rods into the holes.

The head with attached apparatus is photographed laterally by the double exposure method (*Fig.* 339), the plate being supported on three uprights attached perpendicularly to the semicircle; from the negative (*Fig.* 340) thus obtained the position of the missile

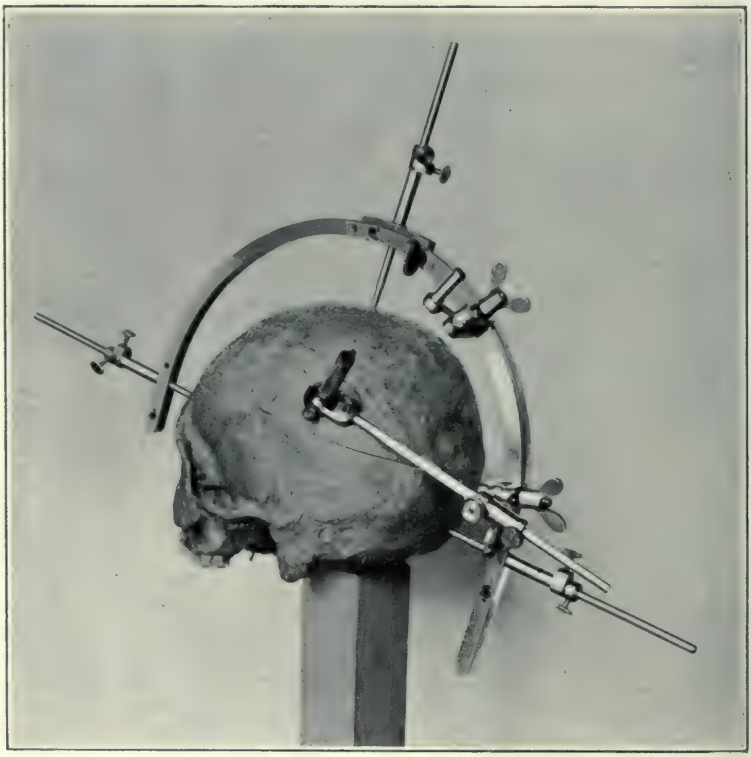


FIG. 342.—Apparatus attached to head at time of operation. The tubular forceps-guide has been placed opposite the wound through which extraction is to be performed. The placing of the guide in any desired position is rendered possible by means of: (1) A ball-and-socket joint controlled by a butterfly nut, supporting (2) A sleeve furnished with two thumb-screws, one of which can suppress longitudinal movement, and the other revolution of the stem which passes through it; and (3) A joint between the tubular part of the guide and the stem (which might be described as a 'one-pronged fork'); this joint can be rendered rigid by tightening the little hexagon nut with a clock-key spanner. When the guide has been placed in the position desired, the butterfly nut of the ball-and-socket joint, and the screw on the sleeve controlling longitudinal movement of the stem, are tightened. The other screw and the hexagon nut are left loose. The result is that the guide-tube is fixed in position, but its direction is still capable of being modified to enable it to aim at the foreign body.

The joints are provided with spring washers. When tightly screwed up they are perfectly rigid; but when unscrewed a little they can be moved with sufficient resistance to prevent the component parts from moving by their mere weight.

relative to the apparatus is determined by the cross-thread method of localizing (*Fig.* 341). This position is marked by the point of a probe fixed to the apparatus in such a way that it can be removed and restored accurately to position whenever necessary.

When the operator is ready to perform extraction, the apparatus, sterilized in any convenient way, is fixed to the head exactly as before, so that it comes to occupy the same relation to the foreign body as at the time of *x*-ray examination (*Fig.* 342). The tubular forceps-guide already alluded to is now placed in position over the wound through which it is proposed to extract the foreign body. On reference to *Figs.* 342, 343, 344, it

will be seen that the forceps-guide is attached to the semicircle by a device which enables it to be placed in any position, and to be fixed rigidly when desired. The end of the tube next the wound is supported in a kind of universal joint, about which the other end is free to move ; but once manipulated into correct position, it can be fixed there securely. The next step is to make it aim accurately in the direction of the missile, and to determine the depth at which the forceps will be able to grasp the objeet. To enable this to be done,

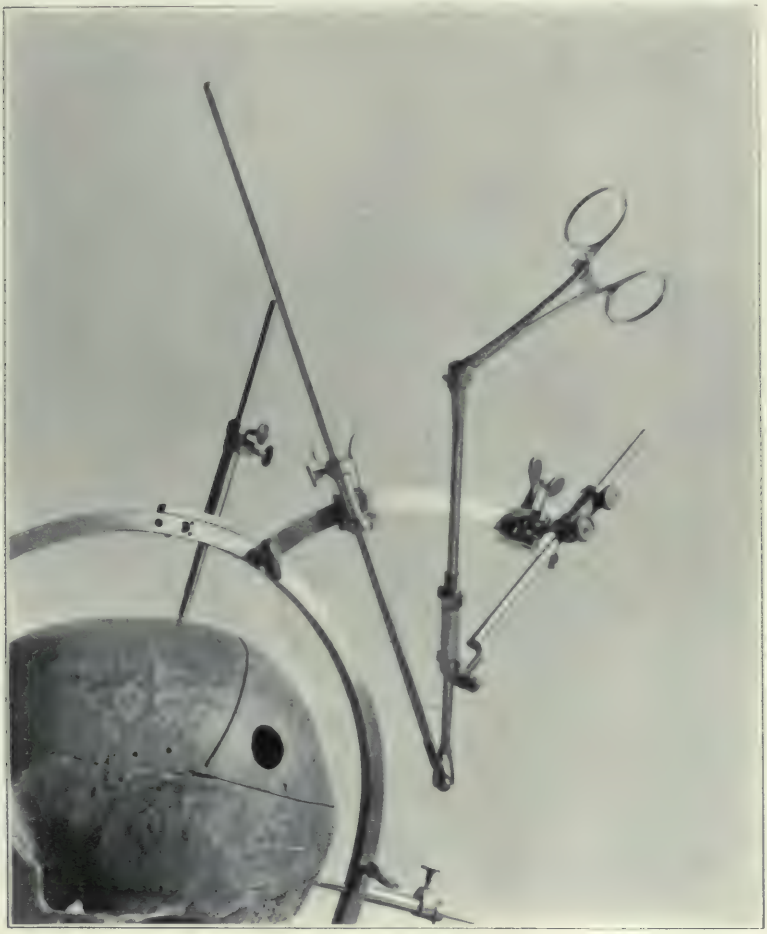


FIG. 343.—The sector carrying probe-guide and forceps-guide has been swung aside. The probe having been placed in position, the forceps, introduced through its guide, has been manipulated to seize the point of the probe. This operation is rendered easier if the point of the probe is covered with a small ball, as shown in the photograph. The forceps is described in the text. Observe the short piece of rubber tube on the stem of the forceps, which has been slid up into contact with the end of the guide-tube.

The probe and forceps must be withdrawn before the sector can be restored to position.

that part of the apparatus which supports the probe-guide and forceps-guide is temporarily swung out of position (*Fig.* 343) by releasing a couple of thumb-screws, this procedure being more convenient than the alternative of removing the whole apparatus from the head. The probe having been placed in position in its guide, the tubular forceps-guide is made to aim correctly by inserting the forceps and manipulating it until it grasps the point of the probe, which, it will be understood, indicates the position of the missile. The forceps-guide is now fixed rigidly in its position, and a short piece of rubber tubing on the stem of

the forceps is slid up into contact with the free end of the guide, to register the depth at which the forceps will be able to grasp the missile. After withdrawing forceps and probe, the part of the apparatus supporting their guides is replaced in position. The forceps-guide comes thus once more opposite the wound, but it now aims correctly at the foreign body (*Fig.* 344).

The forceps, lubricated with a little sterile oil, is introduced through the guide, and gently pushed into the brain until within a short distance of the depth at which the blades can grasp the missile, as indicated by the approach of the short piece of india-rubber tube on the stem to the free end of the forceps-guide. If there is any marked difference in the length of the principal diameters of the missile, the forceps must be given the correct orientation to grasp it by its smallest diameter. It is assumed that the radiographer has formed a fairly accurate opinion of the size, shape, and lie of the missile from

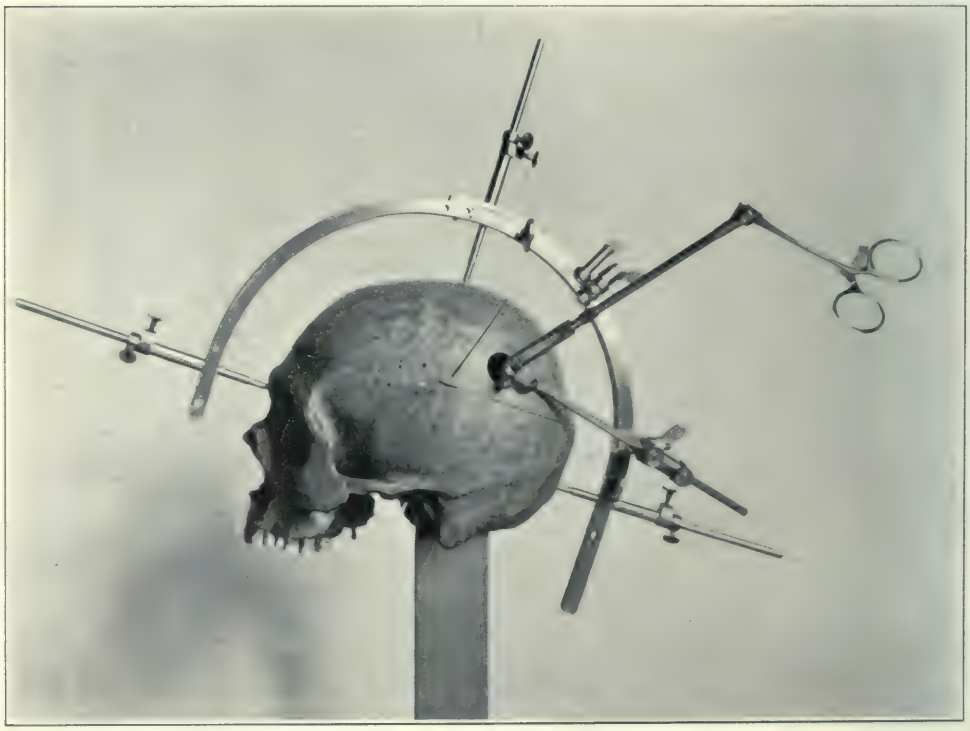


FIG. 344.—Sector again in position. The forceps-guide now has correct direction, i.e., it aims at the foreign body. The forceps has been introduced closed until within a short distance of the foreign body, as indicated by the approach of the piece of rubber tubing on its stem to the end of the guide. It is at this stage that the jaws should be opened before the final advancement to grasp the foreign body. Observe the graduated scale near the finger-rings of the forceps which indicates the degree of separation of the jaws.

preliminary examination, preferably from two plates taken in planes at a right angle. The estimated size of the missile will determine how far the forceps should be introduced before opening the jaws, and also the degree of opening necessary to enable the missile to be grasped. The jaws having been opened to the extent required, as indicated by a small scale near the loops of the handles, the forceps is introduced the remainder of the distance, i.e., until the piece of rubber tube on the stem comes into contact with the free end of the guide. The jaws should now embrace the foreign body, and the sensation on closing the handles should enable the operator to feel that it has been grasped. On withdrawing the forceps with the missile in its grasp, progress will be arrested as soon

as the jaws—now open to an extent depending on the size of the missile—come in contact with the guide. To meet this difficulty, the guide is made in two sections, one of which can easily be slid off, enabling extraction to be completed without altering the position of the guide.

As the fixed section of the guide-tube remains in position, it can be used to facilitate the introduction of a drain, if the operator so desires. As an example, a glove finger or a small roll of 'rubber dam' is seized in the forceps by means of which extraction has just been performed, and is introduced with perfect accuracy into the cavity recently occupied by the missile, by passing the forceps along the guide to the depth indicated by the rubber collar on the stem. The operation is completed in the usual way, after removing the apparatus.

In this brief sketch it has been necessary to suppress a great deal of technical detail connected with localization; but it may be stated that the special technique of the process renders it accurate within a negligible degree of error. I have also omitted much that might be said on the subject of extraction.

As regards mechanical details of the apparatus, the illustrations, with the explanatory notes accompanying them, must for the present suffice; but an exception must be made in favour of the forceps, which requires special mention. This resembles 'crocodile' forceps in general outline, but differs from them in that both jaws open and close together and equally. The stem is long, slender, and cylindrical, 5 mm. in diameter, about the size of a No. 8 catheter. The jaws are slightly hollowed, and finely serrated. They taper together to a sharp flat end, so that when closed the instrument resembles a long slender screw-driver. Being considerably less in diameter than the average foreign body usually described as 'worth going for,' the forceps possesses obvious advantages over ordinary means of extraction. Its sectional area is only one-sixteenth of that of the average forefinger; it goes straight to its work without any 'hunting about'; and its length is such that, theoretically, it can be used to extract from any depth. It is to be noticed that the depth of the foreign body does not in any way influence the accuracy of the instrument. In one case, for instance, I extracted a small piece of metal along its track of entry from a depth of 3½ in. In cases of late extraction performed through a healing wound, the use of the forceps should reduce the risk of breaking down the adhesions which form between the meninges and neighbouring tissues and tend to limit the spread of sepsis along the surface of the brain. Extraction of foreign bodies giving rise to symptoms long after healing of the original wound, might be performed with much less mechanical trauma than is possible by ordinary means. In short, when (as in most cases) the diameter of the foreign body exceeds that of the forceps, the purely mechanical damage done in the course of extraction will usually be limited to that necessarily caused by the missile itself.

To illustrate the application of the method, I append short descriptions of two cases, one of which is chosen because it shows under what circumstances failure is apt to occur.

Case 1.—Pte. S. H., Royal Irish Rifles, age 23, wounded Aug. 16, 1917, was admitted to a base hospital on Aug. 21, under the care of Lieut.-Col. T. P. Dunhill, A.A.M.C. The entrance wound was on the right side, at the level of the lobe of the ear, and the track passed inwards and upwards, through the ascending ramus of the jaw and the base of the skull, and the missile, having crossed the mid-line, finally came to rest in the posterior part of the left frontal lobe, ½ in. from the superior longitudinal fissure and 1½ in. from the surface.

Abstract of Clinical Notes.—Aug. 21, both eyes closed from very great ecchymosis of lids, and subconjunctival œdema. *Right eye*—some proptosis; cornea clear; iris bright; pupil larger than that of left eye; ocular movements limited; definite optic neuritis; swelling 1·5 D. *Left eye*—normal except for indistinctness of outline of disc, with no definite swelling. Can count fingers with either eye. Diplopia except when looking straight ahead. Babinski great-toe phenomenon present. No other neurological signs. Temperature 98°–99°; pulse 68–58.

Aug. 26.—Optic neuritis more marked. *Right eye*—swelling 1D. *Left eye*—swelling 3D. Temperature 100°; pulse 44.

Col. Dunhill kindly invited my collaboration in this case, and operation was performed on Aug. 27. After localization had been completed in the manner already outlined, Col. Dunhill exposed the dura through a large quadrilateral opening whose centre was about 2 in. above the left external angular process, and the forceps, having been given the proper setting, was introduced through a small crucial incision. This mode of approach was chosen because it was obviously impossible to extract the missile along its track of entry. The attempt to grasp the missile was not successful, but the reason for failure was at once evident when pus and gas bubbles gushed out along the stem of the forceps: an abscess cavity existed in which the missile was free to move. Foreseeing this eventuality, we had given orders that the patient was not to be moved from the position in which he was *x*-rayed until the operation was completed; but as he was carried from the *x*-ray room to the adjoining theatre in the arms of orderlies, there is little doubt but that the foreign body was given an opportunity of moving. The abscess cavity contained about a drachm of pus mixed with gas bubbles, and on exploration the foreign body was detected lying in it, as far as could be judged about ½ in. from the position where it was expected to be found. It was 'vomited out' soon after exploration of the cavity, and proved to be a chip of steel 3 or 4 mm. thick, whose outline was irregularly ovoid, with a major axis of about 12 mm. A glove-finger drain was inserted, and the wound partially closed.

A month after the operation, both wounds (entrance and operation) were completely healed, and there was no pain. The oculist reported that there was no swelling of the discs, and apart from some want of definition of their edges, nothing abnormal to be detected in the fundi; the right eye had receded, but its movements were still limited, and there was diplopia, with upward and downward movements. The patient was evacuated to England about the beginning of December, 1917, but he had been walking about long before that date.

It must be acknowledged that the attempt to extract the foreign body with forceps was a failure; but the operation was successful in every other detail, and illustrates the use of the apparatus in its minor rôle—as an indicator.

Case 2.—Pte. J. B. W., 2nd H.A.C., age 29, wounded Oct. 9, 1917, was admitted to another base hospital two days later. The wound of entry was in the left temporal region. The notes on the case record partial aphasia, right hemiplegia, right knee-jerk absent, extensor response to plantar stimulation on right side, bladder and rectum normal, temperature normal, pulse 84. *X*-ray examination (stereoscopic plates) showed the presence of a small foreign body in the left side of the brain, in the region of the upper end of the Rolandic area, its depth from the surface being estimated at 3½ cm. It had entered the skull through a small punctured fracture 1¼ in. posterior to the external angular process, and immediately behind the groove for the anterior division of the middle meningeal artery.

As the patient's condition seemed to be getting worse, operation was performed on Oct. 16. The missile was localized in the manner already described, and as there was a considerable interval between it and its wound of entry, it was judged expedient to extract it through a fresh wound. Accordingly, Major G. de la Cour exposed the dura mater between the left parietal eminence and the sagittal suture, by removing bone of the size of a two-shilling piece. The apparatus having been replaced on the skull, the direction and depth of the missile were determined as previously described. A small incision was made in the dura, and the forceps was advanced through the brain with the proper orientation. The missile was grasped and removed without the slightest difficulty. It was a piece of steel, 10 mm. long by 5 mm. broad. As there was no evidence of sepsis, the wound was closed without drainage. The wound of entry appeared clean, and so received no special treatment.

A day or two after operation, considerable improvement in the general condition was noted, the aphasia was markedly less, and the patient was able to recognize the man in the adjoining bed. His further progress was rapid, and he was evacuated to England ten days after operation.

A letter from England, dated Dec. 27, 1917 (about ten weeks after operation), from which I quote a few lines, records continued progress:—

> I am glad to tell you he is going on splendidly. He has free use of his right leg, and it is just his foot that is not working now. His right arm also is going on well; he can wave it about, and almost shake hands. The fingers have not much use so far, so he is unable to write. He can read, and he never feels any pain in his head.
>
> I notice a difference in him every week, and he is so cheerful. His voice is all right again; at first he used to hesitate rather a lot. Now he says that if he speaks slowly he does not find any words difficult.

The negative reproduced in *Fig.* 340 belongs to this case, and illustrates the only difficulty that occurred in the operation. The incision for the posterior fixing-rod was made a trifle too low, just below instead of just above the external occipital protuberance, and the tough ligamentum nuchæ made it a little difficult to fit the fixing-rod into the hole made to receive it in the outer table of the skull.

The fact that the instrument is designed primarily to perform extraction, and not merely to facilitate it, should serve to distinguish it from the many varieties of indicating instruments already in use. Though they are often of value in other parts of the body, where a good exposure can be obtained and exploration does little harm, such instruments are obviously less suited for use in brain cases.

It is inevitable that any written description must convey the impression to the reader that the use of the apparatus is full of complexities, but five minutes' demonstration with a skull would show that such is not really the case. Provided that the instrument is used with care and exactitude—much of the technique for ensuring which is omitted from this description—there is nothing difficult about it.

With a few minor exceptions the whole of the apparatus has been made to my design by a clever French mechanic.

In conclusion, I have to thank the commanding officers of the hospitals in which the two above-mentioned cases were treated, Colonel J. A. Dick, A.A.M.C., and Lieutenant-Colonel S. G. Butler, D.S.O., R.A.M.C., for kindly allowing me to report them.

A STUDY OF A SERIES OF PERIPHERAL NERVE INJURIES FROM A SURGICAL ASPECT.

By Brevet-Major J. L. JOYCE, R.A.M.C.T.

SUMMARY OF CONTENTS.

Introduction.
Material and Records.
Tables Showing Classifications of Cases and Operations.
Illustrative Cases :—
1. Nerve Transplants and Double Lateral Implantations.
2. Sutures.
3. Neurolyses :—
a. Complete physiological divisions.
b. Incomplete physiological divisions.
c. Painful lesions.
d. Cases associated with aneurysms and brachial plexus injuries.
4. Alternative Operations.
5. The Unoperated Cases.
Some General Reflections.
Conclusions.

INTRODUCTION.

This paper is devoted to the study of the surgical treatment of war-injured nerves. The writer has dwelt mainly on the operative treatment. Not that he minimizes the importance of the pre-operative and post-operative treatment, involving the various resources of physiotherapy and the employment of prosthetic appliances. On the contrary, the importance of each item of such treatment is thought to be of sufficient magnitude to deserve a separate and special study. In the treatment of every case of nerve injury, frequent collaboration and consultation between surgeon, neurologist, masseur, and electrotherapeutist is a *sine qua non* of a successful result.

Before the war nerve injuries were relatively few in number. The surgeon had at his disposal many objective findings from physiological and histological research, but few if any case-histories from which to draw conclusions. Thus, it seems to the writer, has a tendency sprung up to elucidate and confirm the former by the latter. Such a method can only lead to artificial conceptions. Now that such a large amount of clinical material has become available, the opposite method must be adopted. With this end in view, and in the hope that fresh light may be thrown on the operative treatment of injured nerves, the study of the following series of cases has been undertaken.

The illustrations are the work of Private Shaw, R.A.M.C.; the majority of them are finished copies of drawings made by the writer immediately after operation; the remainder are original.

My thanks are due to Captain Johnston, R.A.M.C., for many useful criticisms, and to my commanding officer, Brevet-Colonel W. J. Maurice, R.A.M.C.T., for his permission to make use of the case-histories.

MATERIAL AND RECORDS.

During the period May, 1915, to April, 1918, 150 cases of injured peripheral nerves have been under the care of the writer in a general surgical block of a war hospital. Some 50 additional cases have been recorded since that date in the special military surgical section of the same hospital, and many others have passed under observation. A few of the latter are recorded in the text, but are not indicated in the statistical portion of the paper, which is concerned only with those admitted before April, 1918.

At the beginning no special method of recording nerve cases was adopted, but the effort to improve and standardize the records has culminated in the adoption of a case-record book for the specific purpose of recording the case-histories of nerve injuries. The book is composed of loose sheets, which are used as required.* Thus has been effected not only an economy in the labour of note-taking, but the certainty of a thorough and ordered examination of each case.

Every effort has been made to follow up the cases. Patients have not been invalided or discharged until all hopes of recovery have vanished, or until there were clear signs of improvement. After leaving hospital, many have been written to, and in other cases the medical attendants have been communicated with at the patients' homes. Some few have their homes in the district, and have attended over prolonged periods as out-patients; while several have journeyed considerable distances to be seen and examined. One patient was invalided to Canada, and returned to show himself 'cured' eighteen months after a partial neurectomy and suture (*Case* 12).

CLASSIFICATIONS OF CASES AND OPERATIONS.

Table I.—Showing the Number and Distribution of the Cases, and the Relative Frequency of Injury of Different Nerves in the Series.

Nerves Involved	No. of Cases	Relative Frequency of Injury	Percentage
Upper Limb			
Ulnar	23	36	24
Musculospiral	18	19	11
Median	17	30	18
Brachial plexus	13	13	7·5
Median and ulnar	11	—	—
Circumflex	2	2	1·5
Posterior interosseous	2	3	2
Musculocutaneous	1	1	1
Internal cutaneous	1	2	1·5
Suprascapular	1	1	1
Ulnar and posterior interosseous	1	—	—
Median, ulnar, and musculospiral	1	—	—
Median and internal cutaneous	1	—	—
Total	92	107	64·5
Lower Limb			
Sciatic, trunk	18	19	11
„ external division	12	13	7·5
Peroneal	7	8	4·5
Posterior tibial	6	8	4·5
Sciatic, internal division	3	3	2·5
Anterior crural	1	1	1
„ tibial	1	1	1
Obturator	1	1	1
Musculocutaneous	1	1	1
External saphenous	1	2	1·5
Peroneal and posterior tibial	1	—	—
Posterior tibial and external saphenous	1	—	—
Sciatic trunk (left) and sciatic external division (right)	1	—	—
Total	54	57	35·5
Other Nerves			
Supra-orbital	3	—	—
Cervical plexus	1	—	—
Total	4	—	—

* It had been intended to publish the Case Record Book as an appendix to this paper, but owing to the length of the article this has not been possible. The loose forms can be obtained from W. Tregaskis, 401, Oxford Road, Reading.

Table II.—Names of the Nerves, Numbers of each Injured, Clinical Classification, Number of Operations, and Operative Findings.

Nerve	No. of Cases	Clinical Classification	No.	Operated Upon	Operative Findings	No.
Median ..	30	Complete	8	7	Complete section	6
					Neuroma	1
		Incomplete	22	18	Complete section	1
					Neuroma	6
					Neuroma with lateral cicatrix ..	5
					Neuroma with circular cicatrix ..	1
					Lateral notch	1
					Neuroma with lateral notch ..	1
					Pressure of aneurysm	1
					Pressure of aneurysm with neuroma and lateral cicatrix ..	1
					Contusion*	1
Musculospiral ..	19	Complete	18	3	Complete section	3
		Incomplete	1	3	Neuroma with involvement in callus and lateral cicatrix ..	3
Ulnar ..	36	Complete	24	21	Complete section	17
					Neuroma with lateral cicatrix ..	3
					Neuroma with lateral notch ..	1
		Incomplete	12	6	Neuroma with lateral cicatrix ..	3
					Neuroma with circular cicatrix ..	1
					Pressure of aneurysm	2
Brachial plexus ..	13	See under special section dealing with brachial plexus		3	(1) Lateral cicatrix on ulnar and musculospiral	—
					(2) Pressure of aneurysm of axillary artery, with small lateral cicatrix of median	—
					(3) Pressure of aneurysm of axillary artery	—
Circumflex ..	2	Incomplete	2	0	—	—
Posterior interosseous	3	Complete	2	1	Involvement in callus	1
		Incomplete	1	0	—	—
Musculocutaneous	1	Complete	1	1	Involvement in scar	1
Internal cutaneous	2	Complete	1	1	Complete section	1
		Incomplete	1	1	Involvement in scar	1
Suprascapular ..	1	Incomplete	1	0	—	—
Sciatic, trunk ..	19	Complete	8	5	Complete section	3
					Involvement in scar	1
					Nothing macroscopically abnormal	1
		Incomplete	11	5	Neuroma with lateral cicatrix ..	2
					Involvement of sheath with new bone formation†	1
					Foreign body in nerve	1
					Irritation of bone fragments ..	1
Sciatic, external division	13	Complete	6	3	Complete section	2
					Neuroma with lateral cicatrix ..	1
		Incomplete	7	2	Neuroma with lateral cicatrix ..	2

* Operation at time of injury.

† Associated with traumatic myositis ossificans.

Table continued on opposite page.

Table II.—Continued.

Nerve	No. of Cases	Clinical Classification	No.	Operated Upon	Operative Findings	No.
Peroneal ..	8	Complete	6	4	Complete section	1
					Neuroma with lateral notch ..	1
					Neuroma and involvement in callus	1
					Pressure of stretching over deformed bone	1
		Incomplete	2	0	—	—
Posterior tibial ..	8	Complete	1	1	Neuroma with lateral cicatrix ..	1
		Incomplete	7	2	Neuroma with lateral notch ..	1
					Neuroma	1
Sciatic, internal division	3	Incomplete	3	3	Neuroma with lateral cicatrix ..	1
Anterior crural	1	Incomplete	1	1	Neuroma with lateral cicatrix ..	1
External saphenous	2	Complete	2	2	Complete section	2
Anterior tibial ..	1	Incomplete	1	0	—	—
Obturator ..	1	Incomplete	1	0	—	—
Musculocutaneous	1	Incomplete	1	0	—	—

Table III.—Summary of Table II.

(*Injuries of the Cervical and Brachial Plexuses and Cranial Nerves not included.*)

No. of Cases	Clinical Classification	No.	Operated Upon	Operative Findings	No.
151	Complete	77	49	Complete section	33
				Neuroma	3
				Neuroma with lateral cicatrix	5
				„ with lateral notch	2
				„ with involvement in callus	1
				Involvement in callus	1
				„ scar	2
				Stretching over deformity of bone	1
				Nothing abnormal found	1
	Incomplete	74	41	Complete section	1
				Neuroma	6
				„ with lateral cicatrix	16
				„ „ circular cicatrix	1
				„ „ lateral notch	2
				„ „ involvement in callus and lateral cicatrix	3
				Lateral notch	3
				Involvement in new bone formation	1
				„ scar	1
				Foreign body in nerve	1
				Irritation of bone fragments	1
				Pressure of aneurysm	3
				„ „ with neuroma and lateral cicatrix	1
				Contusion	1

Number of nerves analysed, 151. Number of operations, 90 (= 60 per cent).

Table IV.—Showing the Operations Performed, and Numbers of each.

Operation	No.
Delayed suture	23
Total exsection and suture	6
Partial exsection and suture	7
Neurolysis	39
Autogenous transplantation	4
Total exsection and autogenous transplantation	1
Homologous transplantation	1
Double lateral implantation	3
Exploration	6
Total ..	90

ILLUSTRATIVE CASES.

1. NERVE TRANSPLANTS AND DOUBLE LATERAL IMPLANTATIONS.*

This group comprises 5 ulnar, 1 median, 1 sciatic, and 1 posterior tibial lesions in which end-to-end union could not be obtained on account of the long gap between the divided ends.

Of these, two of the ulnar, and the median, sciatic, and posterior tibial cases, were dealt with by autogenous transplants from the radial. One ulnar case was bridged by a homologous transplant of external popliteal nerve. The two remaining ulnar cases were dealt with by double lateral implantation of the divided ends into the median nerve in the forearm.

As nerve grafting has been stated to be of little value, and nerve anastomosis has been condemned,[1] these cases are worth examining in some detail.

A. NERVE TRANSPLANTS.

Case 1.—Pte. T., age 22. Bullet wound of upper third of right forearm, August, 1915. Clinical diagnosis: (1) Complete division of ulnar; (2) Complete division of posterior interosseous.

Operation, Nov. 11.—Complete section of ulnar nerve. Bulb on central end resected until healthy fasciculi were visible. Lower end dealt with similarly. Gap of 5 cm. separating ends, reduced to 2·5 cm. by flexing wrist. Gap bridged by two pieces of radial nerve each 2·5 cm. long removed from forearm (*Fig.* 345). Suture line and transplant wrapped in Cargile membrane. Posterior interosseous nerve freed from callus and wrapped in Cargile membrane.



Fig. 345.—*Case* 1.

Complete section of ulnar in forearm, bridged by two auto-transplants of radial.

Dec. 27: Pin-prick felt on ulnar half of ring finger and over small area on radial side of little finger.

Feb. 16, 1916: Pin-prick everywhere appreciated in palm of hand and radial side of little finger.

March 3, 1918: Painful spots to pin-prick scattered freely over little finger, but pin-prick not everywhere felt. Epicritic sensation defective in little finger. No alteration from normal detected in ring finger nor in that part of hand supplied by ulnar. No loss of sensation in radial area. Formication not obtained, but hypothenar muscles sensitive to pinching. Scarcely any wasting of hypothenar eminence. Interossei still slightly wasted, but much improved, and "still filling out." Hollow between metacarpals of thumb and index finger less evident. Slight, reducible clawing of little finger. Pitre's tests possible, but imperfectly compared with normal hand. Flexor profundus to little and ring fingers, and flexor carpi ulnaris, act normally (lesion below level

* Instead of the name 'nerve grafting,' the writer has followed Sherren in his preference for the term 'nerve transplantation.'

of the branches to these muscles). Extensors of wrist, thumb, and fingers all act normally. Electrical examination: No faradic response in muscles supplied by ulnar or posterior interosseous nerve below level of lesion; extensor muscles react briskly to galvanism; ulnar muscles react well; no polar change.

Summary.—Transplant of two pieces of radial into ulnar. Partial motor and sensory recovery in 28 months.

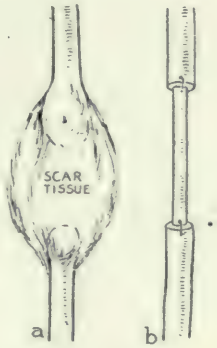


FIG. 346.—*Case* 2.
a. Complete division of ulnar. *b*. Gap bridged by autotransplant of radial.

Case 2.—Pens. A., age 32. Wounded in lower third of left arm, Nov. 8, 1914. Admitted Sept. 23, 1916, with complete ulnar division. Hand neglected, with severe contractures, not relaxing under anæsthetic.

Operation, Oct. 23.—Complete section of ulnar. Resection of bulbs on the central and peripheral segments. Gap of 7·5 cm. remained, reduced to 3·6 cm. by stretching and extending arm. One piece of radial nerve transplanted into gap (*Fig.* 346).

March 20, 1917: Formication on percussion over line of union of transplant with upper segment. Transplant can be felt as a continuous cord in line of nerve. At both ends of transplant a spindle-shaped bulb can be felt.

May 20: Formication produced by percussion along nerve as low as mid forearm, beginning opposite lower end of transplant. Bulb at upper end of transplant has not apparently altered in size, but percussion over it does not produce formication. Return of protopathic sensation over ulnar side of ring finger.

Feb. 25, 1918: Formication to percussion from mid forearm to hypothenar eminence. Flexor carpi ulnaris and flexor profundus digitorum to ring and little fingers act voluntarily and respond to faradism. No return of motor power or faradic response in small muscles of hand. Clawing of ring and little fingers has considerably increased in response to motor recovery of flexor profundus. Bulbs at junction of upper and lower ends of transplant with nerve can still be distinctly felt, and transplant itself is palpable as a rounded cord, comparable in size with the nerve above and below, and freely movable from side to side.

Summary.—Transplant of radial into ulnar above elbow. Formation of bulbs at both ends of transplant in 5 months. Formication to mid forearm in 7 months. Partial motor and sensory recovery in 16 months.

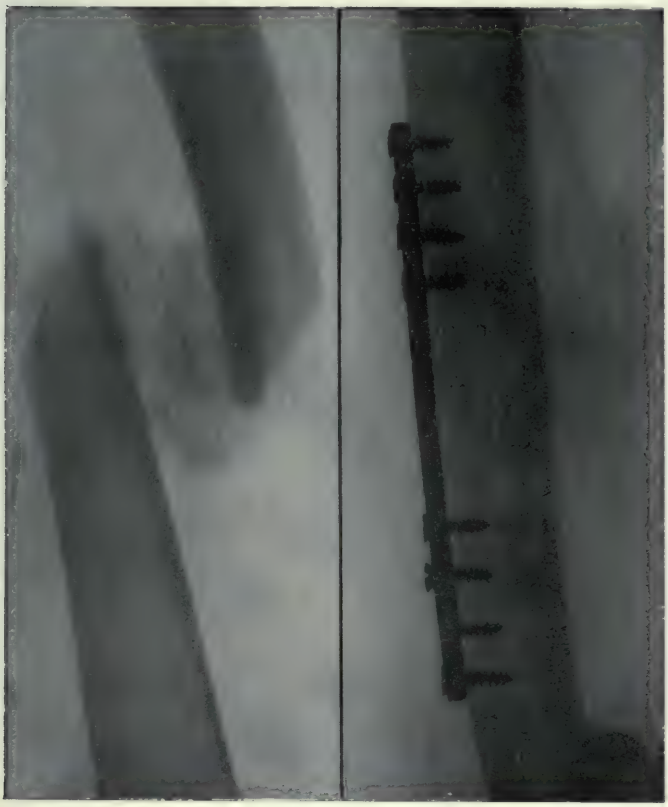


FIG. 347.—*Case* 3.
Compound fracture of femur, before and after plating. Complete division of sciatic, which was involved in callus.

Case 3.—Pte. K., age 21. Bullet wound of left thigh, with compound fracture of middle of femur, July 1, 1916 (*Fig.* 347). Complete division of sciatic nerve.

Aug. 16: Femur plated.

Operation, Nov. 11.—Sciatic found destroyed for 7·5 cm. Both ends bulbous and involved

in large bone callus. After stretching and resection, gap of 2·5 cm. remained. Slight flexion only of knee allowed by stiffness. Gap bridged by three pieces of radial nerve removed from both forearms (*Fig.* 348). Bridge surrounded with Cargile membrane.

Nov. 21: Trophic sores on great toe and inner side of foot.

April 10, 1917: Diminished loss of protopathic sensation. Formication on percussion at apex of popliteal space, i.e., below level of transplant.

May 15: Formication on percussion over lower end of popliteal space and head of fibula. A large oval swelling can be felt by deep palpation of thigh at level of injury. Trophic sores have healed.

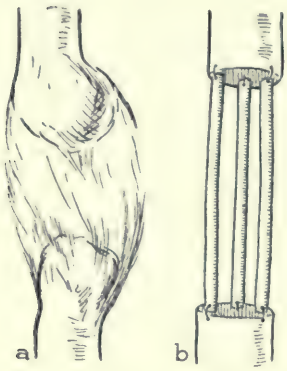


FIG. 348.—*Case* 3.

a. Complete division of sciatic. *b*. Gap bridged by three autotransplants of radial.

February, 1918: Pin-prick still not felt on foot in sensory areas of external and internal popliteal. Paralysis with R.D. of anterior tibial and peroneal muscles. Good voluntary movements in gastrocnemii and soleus, which react to faradism.

Summary.—Three transplants of radial into sciatic. Partial motor and sensory recovery in 15 months.

Cases 4 and 5.—These were the median at the wrist and the posterior tibial above the ankle. In both, a gap was bridged with an autogenous transplant of the radial. In both, six months later, there was considerable diminution in loss of protopathic sensation and formication to percussion below level of transplant. In neither case had voluntary power returned in muscles supplied by the nerves. *Case* 5 had been explored for pain, without benefit, four months previously, when a large neuroma was found, which was wrapped in Cargile membrane. At a second operation the large neuroma was excised, the Cargile membrane was found practically absorbed, and the nerve was lying free from adhesions.

Summary.—Transplants of radial into median and posterior tibial. Some sensory recovery in 6 months. Cargile membrane nearly absorbed after 4 months.

A further case throwing light on some of the problems of nerve transplantations, but not included in the statistical cases, was that of a youth who had had elsewhere a portion of his radial transplanted into a gap in the ulnar in the upper third of the right forearm a year previously, without any recovery of sensation or motor power.

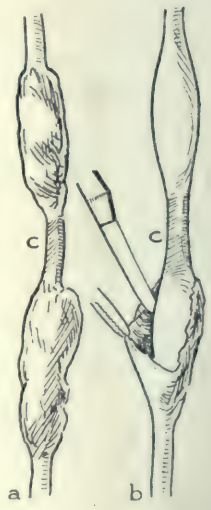


FIG. 349.—*Case* 6.

Complete division of ulnar with autotransplant from radial. *a*. One year after first operation, showing hypertrophy of transplant and formation of spindles. *b*. Neurolysis capsulectomy. *c*. Transplant.

Case 6.—Pte. P., age 19. Bullet wound of upper third of left forearm, Jan. 20, 1917.

Operation, July: Complete section of ulnar. Gap of 3·5 cm. bridged by autotransplant of radial.

August, 1918: Complete paralysis with R.D. of ulnar muscles, and complete sensory loss (*Fig.* 350).

Operation, August, 1918.—Explored. Large oval bulb forming a typical neuroma, densely adherent to surrounding muscles, was found at upper end of transplant. Bulb tapered into transplant, which, although tightly compressed by dense scar, was seen when liberated to resemble normal nerve in size, shape, and consistency. A smaller but similar bulb was found at lower end of transplant, which tapered off into nerve below. The transplant, originally a portion of the radial, had hypertrophied until it equalled in size the nerve into which it had been transplanted (*Fig.* 349).

October: Four months after neurolysis, formication elicited at point 5 cm. above wrist—a spread downwards of 170 mm. in 79 days. Protopathic sensation completely returned over ulnar side of ring finger (*Fig.* 350).

Summary.—Autogenous transplant of radial into ulnar. Formation of bulbs and hypertrophy of transplant, but no recovery, in 13 months. Some sensory recovery and progress of formication 2 months after neurolysis.

Case 7.—Pte. G., age 36. Shell wound of right elbow, March 15, 1917. Severe comminution of upper end of ulna implicating elbow-joint, which had been partially excised. Complete division of ulnar nerve.

Operation Jan. 5, 1918.—Twelve centimetres of ulnar nerve completely destroyed. Upper and lower segments translated to front of elbow, and joint flexed. Gap of 7·5 c.m. Bridge of 7·5 cm. of external popliteal nerve, previously removed from case of irreparable injury to anterior tibial and peroneal nerves (*Fig.* 351). Catgut not being available, sutures of fine black thread were used. Cargile-membrane covering.

August: No recovery of sensation to pin-prick. Formication on percussion not elicited below upper level of transplant. No sign of motor recovery.

Second Operation, August 5.—Nerve explored. Upper segment found swollen and ending in a large soft spindle-shaped neuroma at its junction with transplant. Black-thread sutures still visible, occupying position of greatest diameter of bulb. Cargile membrane completely absorbed. Passing downwards, transplant retained its shape, colour, and individuality. Near lower end transplant rather thinned. Transplant as a whole rather flatter and smaller than nerve into which it had been transplanted. A second neuroma—smaller than the upper one—was found at junction of transplant with lower segment. Here again the black-thread sutures were in the position of the greatest diameter of the bulb. No conduction of faradic current through transplant. The transplant, which originally had a larger diameter than that of the ulnar nerve, had slightly but quite definitely wasted. Bulbs and transplant freed from scar tissue (*Fig.* 351).

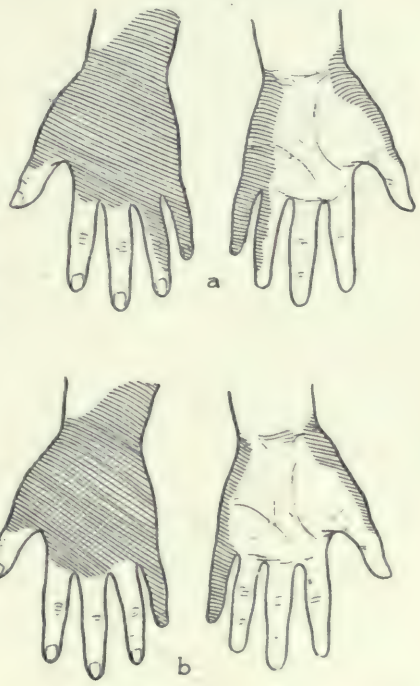


FIG. 350.—*Case* 6.

a. Showing loss of sensation from complete division of ulnar, bridged by 3·5 cm. of radial from upper third of forearm, one year after operation.

b. Extent of recovery of protopathic sensation two months after neurolysis capsulectomy.

October: Formication to percussion 5 cm. below lower end of transplant.

Summary.—Homologous transplant of external popliteal into ulnar. Formation of spindles, involving nerve and transplant at both ends. Wasting of transplant. No recovery in 7 months. Progressive formication below level of transplant 2 months after neurolysis.

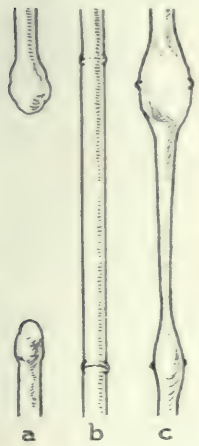


FIG. 351.—*Case* 7.

a. Complete division of ulnar, with gap of 7·5 cm. *b*. Gap bridged with homologous transplant of external popliteal. *c*. Seven months later, showing formation of spindles at both ends of transplant, and position of black-thread sutures.

Nerve transplantation has had a sound experimental basis since the experiments of Phillipeaux and Vulpian in 1870, and has been employed in treatment with satisfactory results since 1888. Mayo Robson[2] operated upon and reported the first successful case. Owing to the War, many opportunities for nerve transplantation have presented themselves, but there is still some difference of opinion on the value of the operation. Thus, Moynihan[1] writes, "Nerve grafting is of little value," and Rawling[3] says, "Grafting, implantation, etc., are comparatively useless." On the other hand, Jocelyn Swan[4] reports two cases of motor recovery following nerve grafts, and says, "I think it is a mistake to damn nerve grafting where the ends cannot be approximated, a state of things which is bound to occur to surgeons who see many of these cases." Among the French school, Benisty[5]

says, "The results of nerve grafting, which *a priori* appears to be a logical procedure, cannot yet be appreciated, since regeneration is beset with difficulties and takes place but slowly." On the other hand, Delagenière[6] reports from Tinel's clinic 9 cases of musculospiral grafts with 3 almost complete successes.

Cases 2 and 3 show that both sensory and motor recovery do occur after nerve transplantation, although in neither case was recovery complete. *Cases* 4 and 5 have improved, while in *Cases* 6 and 7 axis cylinders have now penetrated into the lower segments. Even a measure of recovery is better than none at all, and it has yet to be seen whether one or more of these cases will not ultimately recover completely. Recovery after a nerve transplantation certainly occurs much more slowly than after an end-to-end suture; but the writer agrees with Swan that it is a mistake to condemn nerve transplantation, and believes that with a larger knowledge of the processes involved, and a wider experience of technical details, the results of nerve transplantation are likely to compare favourably with those of end-to-end suture.

Apart from the possibility of recovery after nerve transplantation, the seven cases described possess many other points of theoretical and practical interest. Thus, *Cases* 2 and 6 show—the first by palpation, the second by inspection—that autogenous grafts hypertrophy and may ultimately grow to the same size as the nerve into which they are transplanted; while in *Case* 7 a homologous transplant, originally larger than the receiving nerve, diminished in size.

Cases 2, 6, and 7 show how transplants unite with the receiving nerve at either end by the formation of spindle-shaped neuromata, the larger at the central end. In all these cases the bulb at the lower end of the transplant had formed before any signs could be detected that axis cylinders had reached this level from the central segment.

Case 7 demonstrated by the position of the black-thread sutures that the neuromata were formed partly in the original nerve ends and partly in the ends of the transplant, and suggested that not only the nerve but the transplant had a share in their production.

In *Case* 6, five months elapsed before formication was elicited by percussion at a lower level than the transplant. Thereafter it spread with comparative rapidity down the distal segment of the nerve.

In *Case* 3, there could be detected by palpation a large neuroma which from its size must have involved both ends of the nerve as well as the three transplants. Through the medium of this neuroma regeneration of the distal segment occurred, and motor recovery in certain of the muscles ensued.

In *Cases* 6 and 7, the constricting effect of the surrounding scar was the important factor in preventing recovery. After its removal, neurotization of the transplant and lower segment occurred quickly.

B. DOUBLE LATERAL IMPLANTATIONS.

While nerve transplantation has been damned by faint praise, the operation of double lateral implantation has, by the majority of writers on the surgical treatment of nerve injuries, been directly condemned. Thus, Benisty, speaking of operations which "must be rejected as illogical," especially mentions "the grafting of the central end on to a healthy neighbouring nerve, or the peripheral end on to a neighbouring mixed nerve." Moynihan writes, "Nerve anastomosis is to be sharply condemned." Tinel writes, "Lateral implantations, transplantations of one nerve into the other, are almost always useless, and often mischievous, operations."

In what follows, the writer refers to the special case of double lateral implantation of the ulnar into the median in the forearm. In this particular case the operation is not only harmless, but when the ulnar nerve in the forearm has been destroyed over a wide extent, is capable of producing good results. Three cases of this operation have been performed, but only one has been followed long enough to speak of the ultimate result. The other two confirm the view that the operation is a harmless one.

Case 8.—Pte. F., age 25. Shell wound of left forearm, May 28, 1915. In hospital at home 6 weeks.

July: Sent to Gallipoli.

December: Returned to England with enteric.

January, 1916: Admitted with advanced irreducible clawing of all fingers. Complete ulnar division, complicated by a Volkmann's ischæmic contracture.

Operation, February.—Ten centimetres of ulnar nerve totally destroyed. Well-formed bulb at central end. Resection of bulbs and excision of intervening scar—gap 13 cm. Approximately one-third of circumference of median on ulnar side was divided at two points 16 cm. apart. Upper and lower ends of ulnar implanted into the median in manner shown in *Fig.* 352.

Day following: Loss of sensation to cotton-wool over median area of ring, middle, and index fingers. Sensation to pin-prick lost over radial half of ring finger, middle finger, and ulnar half of index finger (*Fig.* 353). Thumb not affected. Opponens pollicis, abductor brevis pollicis, and first lumbrical acting normally.



FIG. 352.—*Case* 8.

Double lateral implantation of ulnar into median.

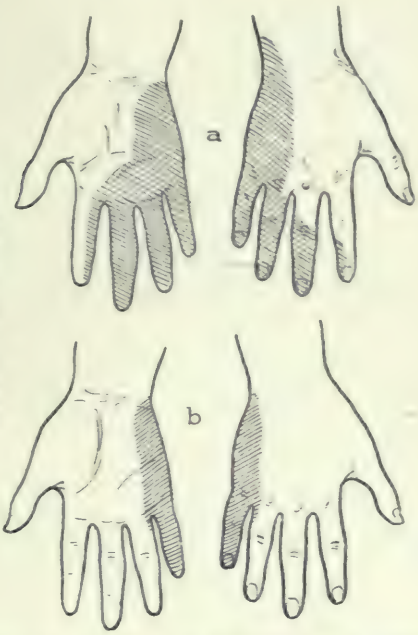


FIG. 353.—*Case* 8.

a. Sensory loss to pin-prick after double lateral implantation involving division of ulnar third of median nerve in forearm at two points 15 cm. apart. *b*. Extent of recovery after 6 months.

April: Flexor contracture of fingers increased.

Operation, April.—Superficial and deep flexors of fingers lengthened. Distal implantation examined. Where distal segment of ulnar joined median, there was a small but distinct bulb, olive-shaped, and involving approximately equal amounts of the two nerves (*Fig.* 354).

August: No recovery of motor power in ulnar muscles. Pin-prick perfectly appreciated in whole of index and middle fingers, over radial half of ring finger, and near base of ring finger on ulnar side (*Fig.* 353).



FIG. 354.—*Case* 8.

Showing formation of spindle involving both nerves at lower end of double lateral implantation into median.

Although unable to examine this case again, the writer has heard by letter from the patient; and Sir Thomas Myles, Consulting Surgeon, Irish Command, kindly made inquiries and sent a letter from the patient's medical officer, Mr. E. D. Thompson. The following are extracts from their letters:—

Extract from letter from patient, dated Nov. 28, 1917.—

"I have nearly all the feeling restored to my hand, the most sensitive being the little finger. It would be quite surprising to you to see how the hand has improved since your operation."

Extract from letter to Sir Thomas Myles from Mr. E. D. Thompson, dated Feb. 9, 1918.—

"The man is wonderfully well. He can close all his fingers, and give a good grip. He has also uniform sensation in both back and front of hand. He can pick up a pin quite easily. The feeling is not quite as good as in his right hand, but he says both the power and sensation are getting better."

Summary.—Double lateral implantation of ulnar into median in forearm, followed by some sensory loss in median area. Recovery of sensibility to pin-prick in median area in 6 months. Some motor and sensory recovery in ulnar area in 24 months.



FIG. 355.

Diagram representing pedicled neurovascular autotransplant (shaded portion) in a case of double lateral implantation of divided nerve into a neighbouring healthy nerve trunk.

The writer is aware that proof of regeneration in the distal segment of the ulnar in the above case is not complete, but the man is still in the Army, and has a useful hand.

The two other cases operated on in this manner have not been watched long enough to report on the result; but in neither case was there any greater loss of sensation in the fingers from dividing a third of the circumference of the median on the ulnar side than has been recorded in *Case* 8. The fact that the ulnar third of the circumference of the median nerve in the forearm subserves sensation only in the ring, middle, and index fingers has been confirmed by the writer on many occasions in cases of incomplete division of this nerve explored by operation.

Instead of regarding the operation as an illogical procedure, the writer believes that the portion of the median nerve between the two lateral cuts acts as a pedicled neurovascular autotransplant (*Fig.* 355), and is more likely to succeed than a free autotransplant.

2. SUTURES.

The following has been the method of suture in the majority of cases. A long skin incision is made, any dense adherent scars being excised whenever possible. Small sterilized cloths, to the under side of which is sewn a layer of jaconet, are clipped to the subcutaneous fascia so as to exclude completely skin contamination of sutures, swabs, and instruments for the remainder of the operation. The upper end of the nerve is usually defined first, and the bulb carefully dissected from adhesions to the surrounding structures. The lower end is then sought, found, and dealt with in the same way. The intervening scar is carefully excised. All the chief bleeding points are ligatured, and all oozing is checked by gauze pressure, oversewing, or by swabbing out the wound with warm peroxide of hydrogen (5 vols.) or adrenalin (1–1000). A great point is made of obtaining a dry wound before proceeding with the next stage of the operation.

When the wound is quite dry, the gap between the divided ends is carefully measured, and a rough estimation made of what this will be when the end bulbs have been resected. The proximal end of the nerve is now stretched, and a decision made whether any other steps are necessary in order to bring the ends together without tension. If such be the case, these are then carried out.

The bulb on the central end is now removed in successive slices with a sharp knife until healthy nerve fasciculi are seen protruding from the cut face of the nerve. A similar resection of the distal segment is made. A tension suture of fine catgut is now passed through the centre of both segments, and the ends are drawn together. Two continuous sutures of the finest catgut procurable draw the sheath together, one suture being used for each half of the circumference of the nerve. At this stage the tension suture is generally removed, but if there has been any difficulty in drawing the ends of the nerve together, it is tied and left *in situ*.

The suture line, and the nerve for 2½ cm. on either side, have been in many cases wrapped in Cargile membrane. The membrane, which has been placed in 1–500 perchloride of mercury at the beginning of the operation, is thoroughly washed in normal saline, and a piece 5 cm. long and one and a half times as broad as the circumference of the nerve, is cut and insinuated under the nerve. The membrane is then carefully

wrapped round the nerve. In some cases, free or pedunculated flaps of fat or fascia have been used as a covering. In others no protection has been used, the nerve being placed between healthy muscles, with or without smearing the suture line with sterilized paraffin.

The muscles, which have been drawn out of the way with retractors, are now allowed to fall into position, and the deep and superficial fascia is carefully closed with catgut sutures. The skin is closed with interrupted salmon-gut sutures.

This method is not original: similar procedures have been described by many other workers; but in order that certain points in technique may be discussed in view of the results obtained, it has been described in some detail.

One of the difficulties in comparing results in nerve work is to know what is meant by such terms as 'recovery,' 'improvement,' etc. It is quite certain that after delayed nerve suture, complete recovery, in the sense that no differences can be found between the normal and affected limb, is seldom if ever attained; there remains an incomplete recovery of the finer forms of sensation, some slight wasting of the affected muscles, or a greater liability to fatigue on the affected side. In order, however, to tabulate and compare results, the use of such terms is necessary; and in what follows, the terms 'Recovery,' 'Considerable improvement' 'Improvement,' and 'No result' are used.

'Recovery' denotes complete return of protopathic sensation, recovery of useful voluntary movements in all the affected muscles, with return of faradic response.

'Considerable improvement' denotes complete return of protopathic sensation, recovery of some voluntary movements in affected muscles, with or without response to faradism.

'Improvement' denotes some return of protopathic sensation, with or without early voluntary twitchings of one or more of the affected muscles, with or without response to faradism, and definite and progressive formication on percussion over the nerve below the level of the lesion.

'No result' comprises all other cases, and includes cases lost sight of or transferred to other hospitals before sufficient time has elapsed to estimate the result; all doubtful cases; and cases watched sufficiently long without any sign of recovery to be classified as failures.

The following table shows the results obtained in a total of 36 cases, made up of 23 cases of delayed suture of completely sectioned nerves, 6 cases of total exsection of affected segments followed by suture, and 7 cases of partial exsections of affected nerves followed by suture.

Table V.—Results of 36 Cases of Nerve Suture.

	Recoveries	Considerable Improvement	Improvement	No Result†
Number of cases	8	6	8	14
Percentage	23	14	23	40
Average time between wound and operation	5 months	6 months	8 months*	—
Average time under observation since operation	15 ,,	7 ,,	3 ,,	7 months
Longest time	24 ,,	12 ,,	7 ,,	24 ,,
Shortest time	8 ,,	4 ,,	1 ,,	1 ,,

* Leaving out one case sutured 2 years and 5 months after injury, average time between wound and operation = 5 months.

† *Analysis of 'No Result' Cases.*—
Failures: Those seen 7 months or longer after operation with no sign of recovery 5
Average time from wound to operation 10 months
(Excluding one case of 19 months, average time between wound and operation = 7 months.)
Average time since operation 11 months
Doubtful: Cases earlier than 7 months after operation with no sign of recovery 9

A. RECOVERED CASES.

The following case illustrates the successive stages of recovery, and is remarkable in its successful issue after ligature of the main vessel of the limb.

Case 9.—Gnr. M., age 22. Shell wound of left popliteal space, May 24, 1915. Common femoral artery tied in a field hospital.

June 1: Admitted with severely suppurating wound behind knee. Foot and ankle œdematous. No pulse palpable at ankle. Black gangrenous patch of skin on point of heel. Complete paralysis with R.D. of all muscles below knee. No sensibility to pin-prick or brush in external or internal popliteal sensory areas.

Oct. 20: Nerve condition unaltered. Wounds have been healed four weeks.

Operation, Oct. 23.—Complete section of both internal and external popliteal nerves with end bulbs. Gap of 3·6 cm. Sutured. Free sleeve of fascia lata.

December: Partial recovery of protopathic sensibility. Ulcer on heel smaller.

March, 1916: Slight voluntary twitchings in gastrocnemii and tibialis anticus.

June: Weak voluntary movements of flexion and extension of foot. Ulcer on heel well. Protopathic sensibility recovered. Sensibility to brush nearly recovered except over toes.

October, 1917: Left leg still slightly smaller than right. Complete recovery of voluntary power in all muscles, with normal electrical responses. Is walking about all day. Left leg becomes slightly more fatigued than right.

Summary.—Improvement in 3 months. Considerable improvement in 8 months. Recovery in 24 months.

Another sciatic case of very similar type to the foregoing deserves recording, owing to the very rapid recovery which followed suture 11 months after the nerve had been divided.

Case 10.—Pte. P., age 20. Shell wound of left thigh, Aug. 6, 1916.

January, 1917: Admitted from his depôt with trophic ulcer of great toe, complete paralysis with R.D. of all muscles below knee, and no sensibility to pin-prick or cotton-wool in external or internal popliteal sensory areas. Refused operation until July, 1917. Nerve condition unaltered.

Operation, July 3.—Condition shown in *Fig.* 356. Nerve stretched, bulbous extremities resected. Knee flexed. Suture. Cargile-membrane protection. After 4 weeks knee gradually extended.

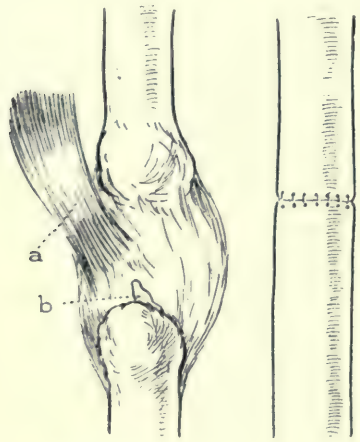


FIG. 356.—*Case* 10.

Condition before and after operation. *a*. Muscle drawn in between divided ends. *b*. Bony projection from posterior surface of femur.

Dec. 9: Voluntary power in calf muscles. Sensibility to pin-prick and brush recovering rapidly. Formication on percussion half-way between knee and ankle, 360 mm. in 160 days—over 2 mm. per day.

June, 1918: Voluntary power strong in calf muscles. Sensibility to pin-prick and brush completely recovered. Trophic ulcer healed.

October: Continued improvement, with return of faradic response and voluntary power in all muscles below knee.

Summary.—Improvement in 5 months. Considerable improvement in 11 months. Recovered in 15 months. Formication to percussion spread down nerve at a rate exceeding 2 mm. per day.

The individuality of nerves from the point of view of the rapidity and completeness with which they regain their motor power, noticed by several writers, was first pointed out by Réné Dumas,[7] but he was disappointed in the sciatic nerve from this point of view. In the writer's experience, the sciatic nerve and both its internal and external divisions, are in this respect second only to the musculospiral.

In four cases recovery followed suture of the external division of the sciatic.

Case 11.—Pte. S., age 19. Shell wound of left thigh, July, 1916. Complete paralysis of anterior tibial and peroneal muscles, with R.D. Pain and tenderness on dorsum of foot, and hyperæsthesia to pin-prick. Sensibility to cotton-wool blunted.

January, 1917: Condition unaltered.

Operation, Jan. 6.—Lateral notch in external division of sciatic, with bulb of upper segment (*Fig.* 357). Resection and suture. Cargile membrane. Knee flexed.

June: Sensibility to pin-prick recovered. Formication on percussion 5 cm. above external malleolus 440 mm.—average over 2 mm. per day. Slight voluntary power in peronei and common extensor.

January, 1918: Still improving. Voluntary power in tibialis anticus.

May: Severe attack of pneumonia. Foot left unsupported.

June: Voluntary power in anterior tibial group lost.

August: Voluntary power has returned in all muscles supplied by external popliteal nerve.

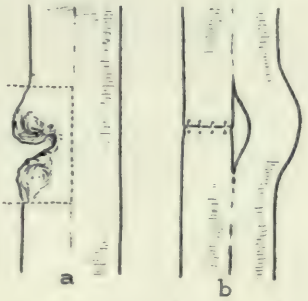


FIG. 357.—*Case* 11.

Lateral notch of external division of sciatic. *a*. Before. *b*. After resection suture.

Summary.—Recovered in 20 months. Recovery interrupted by pneumonia. Formication progressed at rate exceeding 2 mm. per day.

Case 12.—Sgt. P., age 30. Through-and-through bullet wound of left thigh and groin, September, 1916.

November: Complete paralysis with R.D. and sensory loss in external popliteal. Paralysis with R.D. in calf muscles. Voluntary power in small muscles of foot. Excruciating pain in sole of foot.

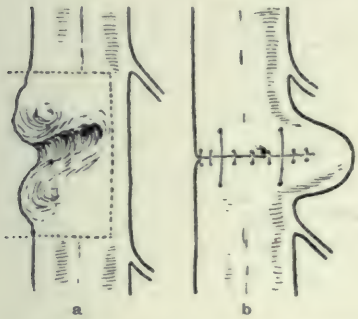


FIG. 358.—*Case* 12.

Lateral notch of sciatic trunk. *a*. Before. *b*. After partial resection suture. Topography of sensory fibres to sole of foot shown on inner side of nerve.

Operation, Nov. 18.—Nerve damaged at level of gluteal fold (*Fig* 358). Partial exsection and suture. Cargile membrane. Flexion of knee.

February, 1917: Pain and tenderness gone. Sensation in sole of foot normal. Voluntary power in small muscles of foot. No recovery in sensory area of external popliteal. All muscles of leg still paralyzed. Invalided to Canada.

June, 1918: Returned for examination. Voluntary power and faradic response in all muscles of leg. No loss of sensibility to pin-prick or cotton-wool.

Summary.—Sensory nerve fibres to sole of foot and motor fibres to small muscles of foot located on internal aspect of internal division of sciatic. Recovery after 20 months.



FIG. 359.—*Case* 13.

Lateral notch of external popliteal before and after resection suture.

Case 13.—Pte. B., age 26. Multiple shrapnel wounds of right leg and thigh, July, 1916.

December: Paralysis with R.D. in all muscles supplied by external popliteal except the tibialis anticus.

Operation, Dec. 14.—Deep lateral notch, with bulb of upper segment, on deep aspect of nerve (*Fig.* 359). Partial resection and suture. Cargile-membrane protection.

May, 1917: Tenotomy of Achilles tendon. Foot retained at right angle in plaster.

August: Voluntary power in all muscles of leg, with faradic response. Can walk well.

Summary.—Recovery after 8 months.

Case 14.—Pte. W., age 27. Bullet wound of right leg, with compound fracture of fibula, July 1, 1916. Complete paralysis with R.D. in all muscles supplied by external popliteal, with corresponding sensory loss.

September: Piece of shrapnel removed from head of fibula. Sinus excised. B.I.P.P. Sutured. Primary union.

March, 1917: No recovery.

Operation, March 8.—Nerve densely bound down and surrounded with callus (*Fig.* 360).

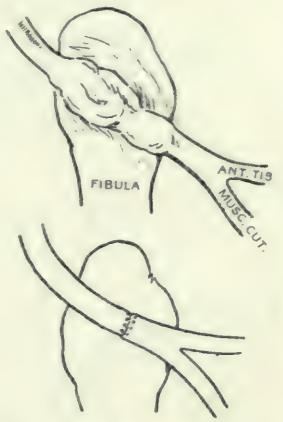


FIG. 360.—*Case* 14.

Complete division of peroneal nerve, with involvement of bulbs and callus. Before and after operation.

Involved part of nerve occupied by hard (? fibrous) mass. Total exsection and suture. Cargile membrane.

May 5: Formication 12 cm. below level of suture. Invalided.

June, 1918, by letter: Complete recovery. Able to raise foot easily and walks well.

Summary.—Average progress of formication in 2 months after suture, 2 mm. per diem. Recovery in 15 months.

The next case is an example of severe causalgia of the median, relieved by exsection and suture.

Case 15.—Cpl. T., age 35. Shrapnel wound of bend of right elbow, September, 1915. No paralysis in median. Severe pain in right hand.

November: Pain has become unbearable. Insomnia. Threatens to commit suicide. Skin of hand dry. Fingers thin, slender, and stiff from disuse. Nails long and bent.

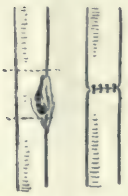


FIG. 361.—*Case* 15. Lateral neuroma of median, causing causalgia. Total exsection and suture.

Operation, November.—Lateral neuroma (*Fig.* 361). Total exsection and suture. Cargile membrane. Elbow flexed.

January, 1916: Rapid recovery of sensation. Cotton-wool and pin-prick everywhere felt in median area except on ulnar side and dorsal surface of middle phalanx, the insensitive area being mapped out by a patch of undesquamated epithelium.

May: Weak voluntary power in all muscles supplied by median, with exception of small muscles of hand. Spindle-shaped swelling easily palpable in course of nerve at level of suture.

March, 1917: Voluntary power in all muscles.

November: Hand practically normal, except still slightly tender in cold weather.

Summary.—Considerable improvement, with formation of nerve spindle, in 7 months. Recovery in 24 months.

The last recovered case is one of complete section of the musculospiral, and is one of the only two examples of suture of this nerve in the series. Three reasons account for the relative rarity of suture of the musculospiral. They are: (1) The ease with which this nerve recovers from lesions other than complete section, either spontaneously, or after a neurolysis; (2) The frequent association of injuries of the nerve with severe fractures of humerus (15 out of 19 cases in this series), followed by extensive formation of callus, making nerve suture difficult and uncertain; (3) The alternative operation for this nerve described by Major-General Sir R. Jones,[8] which, if not the operation of choice, gives results little if at all inferior to those of nerve suture, and in much less time. The case illustrates the bad effect of prolonged extension of the fingers at the metacarpo-phalangeal joints.

Case 16.—Bbdr. S., age 24. Shrapnel wound of left upper arm, November, 1915. Complete paralysis of supinator longus and brevis, and all extensor muscles of forearm, with R.D. No sensory alteration.

Operation, January, 1916.—Three pieces of shrapnel removed. Nerve completely divided in groove, and buried in very dense scar. Suture and Cargile-membrane protection.

May: Voluntary twitchings of extensors of wrist and fingers. Fingers stiff at metacarpo-phalangeal joints from hyperextension on long cock-up splint.

March, 1917, by letter: "My arm is progressing wonderfully. I can raise my wrist up and down. I have got more power in my thumb and first two fingers. I cannot bend my little and third fingers."

Summary.—Improvement in 4 months. Recovery in 14 months.

B. CONSIDERABLY IMPROVED CASES.

The cases of 'considerable improvement' are 3 ulnar lesions, 2 median, and 1 anterior crural.

Most writers are agreed that the ulnar recovers slowly and with difficulty, and the hypothesis has been put forward that this is due to distortion of the nerve pattern. Thus, Gwynne Williams,[9] comparing the results of suture of the musculospiral nerve with those of suture of the median or ulnar, concludes that it must be the composition of the nerve that makes the difference. Two of the three cases which follow suggest that one must look to the small muscles of the hand for the difficulty in recovery. Motor power in the flexor carpi ulnaris and flexor profundus digitorum returns as easily after suture

of the ulnar as it does in the radial extensors after suture of the musculospiral. The slow recovery of the small muscles of the hand may possibly be due to the difficulty of keeping them efficiently relaxed; or it may be explicable on grounds of an inherent property of the muscles themselves, in some way associated with the highly complex movements which they have to execute. The small size of their fleshy bellies may also be a factor of importance.

Case 17.—F. L., age 14. Severe cut of left forearm 7·5 cm. below elbow, March, 1917.

October: Complete paralysis of all ulnar muscles with R.D. and sensory loss in ulnar area. Voluntary power in flexor carpi ulnaris and ulnar half of flexor profundus. Claw hand.

Operation, October, 1917.—Complete section found. Suture. Protection with Cargile membrane and vaseline. Nerve translated to front of elbow, and elbow flexed.

October, 1918: Pin-prick everywhere recovered. Voluntary power in all small muscles of hand. Still loss of finer sensation in little finger.

Summary.—Considerable improvement after 12 months. (Note patient's age.)

Case 18.—Cpl. F., age 29. Shell wound of lower third of left arm, with compound fracture of humerus and injury to ulnar nerve, February, 1918.

June: Complete paralysis with R.D. of all ulnar muscles below elbow. Slight, reducible claw hand. Loss of sensibility to pin-prick and brush in ulnar area. Loss to pin-prick greater than loss to brush.

Operation, June 20.—As in *Fig.* 362.

Aug. 26: Formication to two finger-breadths above wrist—190 mm., an average spread of 2·8 mm. per diem. Protopathic sensation recovering rapidly.

October: Voluntary power in flexor carpi ulnaris, with return of faradic response. Voluntary power in flexor profundus, but still R.D. No return of voluntary power in small muscles of hand. Fingers clawed if splint is removed.

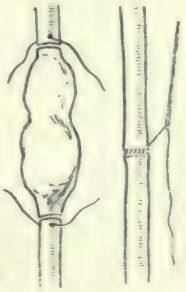


FIG. 362.—*Case* 18. Before and after resection and suture.

Summary.—Recovery of voluntary power in flexor carpi ulnaris and flexor profundus digitorum in 4 months.



FIG. 363.—*Case* 19. *a*. Five centimetres of ulnar destroyed. *b*. After resection suture.

Case 19.—Gnr. L., age 19. Shell wound of left arm, with compound fracture of humerus, lower third, October, 1916.

October, 1917: Complete paralysis of all ulnar muscles below elbow with R.D., and sensory loss in ulnar area. Fibrosis of flexor muscles of forearm.

Operation, October, 1917.—Five centimetres of nerve destroyed—dense scar intervening between two bulbs (*Fig.* 363). Translation of nerve to front of elbow. Flexion of elbow. Resection. Suture. Protection with Cargile membrane.

August, 1918: Complete return of sensibility to pin-prick. Voluntary power and faradic response in flexor carpi ulnaris and flexor profundus digitorum. Hypothenar muscles very tender to pressure. No return of voluntary power in small ulnar muscles of hand.

Summary.—Recovery of flexor carpi ulnaris and flexor profundus in 10 months. Recovery of sensation. No recovery in small muscles of hand.

The first of the next two cases—both sutures of the median—is interesting, because of the fact that, after primary suture performed in France, which failed on account of suppuration of the wound, delayed suture was followed by rapid recovery.

Case 20.—Pte. G., age 23. Shell wound of middle of right arm, October, 1917. Note from C.C.S.: "E. and E. middle of arm, brachial artery thrombosed, tied above and below, median nerve found divided and sutured. Bipp."

December: Wounds healed.

May, 1918: Complete paralysis and R.D. in all median muscles of forearm and hand, with sensory loss in median area. No formication on percussion below level of injury.

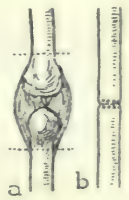


FIG. 364.—*Case* 20. Complete section of median, with bulbs, 8 months after primary suture in wound which suppurated. *a*. Before, *b*. After operation.

Operation, May 25.—Scar excised, 5 cm. gap (*Fig.* 364). Flexion of elbow. Suture. Cargile membrane.

July 28: Sensibility to pin-prick recovering. Formication has progressed 260 mm. below level of suture, an average of 4 mm. per diem.

October: Further recovery of sensation. Voluntary power in flexor carpi radialis, pronator radii teres, and flexor longus pollicis. Faradic response in flexor longus pollicis.

Summary.—Considerable improvement in 5 months.

The second case demonstrates the same topography of the nerve fibres of the median in the forearm which was mentioned when describing the cases of double lateral implantation of the ulnar into the median.



FIG. 365.—*Case* 21.

Lateral neuroma of median on radial side, involving fibres to opponens pollicis and abductor brevis pollicis.

Case 21.—A.-B. S., age 19. Bullet wound of middle of left forearm, with fractured radius, January, 1918.

April: Hyperæsthesia of ring, middle, and index fingers. Brush not felt over median area of thumb. Paralysis and R.D. of opponens pollicis and abductor brevis pollicis. Diagnosis: Neuroma of median on radial side of nerve.

Operation, April.—Diagnosis confirmed (*Fig.* 365). Partial exsection and suture. Cargile membrane.

October: Weak voluntary power in abductor brevis pollicis and opponens pollicis. Incomplete R.D.

Summary.—Considerable improvement in 5 months.

The last case showing 'considerable improvement' is that of an injury to the anterior crural nerve in the groove between the psoas and iliacus muscles in the iliac fossa. Injuries to this nerve are rarely seen, and this example is of peculiar interest in that it produced a true and most intense causalgia in the cutaneous distribution of the nerve.



FIG. 366.—*Case* 22.

Perforating wound of left ilium, involving anterior crural.

Case 22.—Cpl. S., age 28. Through-and-through shell wound of back and abdomen, July, 1917. Foreign body removed from abdominal wall in France. Abdomen opened, through-and-through hole of small intestine 25·3 cm. from duodenojejunal junction closed. Pain in left leg.

Aug. 30: Admitted. Intense pain over front of left knee. Complete paralysis with R.D. in quadriceps extensor, with advanced wasting of muscle. Skin dry, yellow, and resembling parchment.

September: No relief. Patient states he finds life unbearable. Insomnia and loss of appetite. *X* ray shows perforating wound of left ilium (*Fig.* 366). Fragments of bone in aperture. Wound in back suppurating.

October: Excision of wound in back *en masse*. B.I.P.P. and suture. Primary union.

Operation, November.—Oblique incision, parallel to and 1·5 cm. above Poupart's ligament in its outer third, carried upwards and backwards 5 cm. beyond the anterior superior iliac spine. External oblique split and held apart with large retractors. Peritoneum pushed inwards and upwards by gauze dissection. Nerve exposed in groove between psoas and iliacus. Large lateral neuroma found, adherent to scar and muscles (*Fig.* 367). Total exsection of affected segment. Suture.

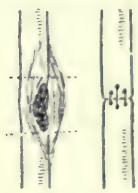


FIG. 367.—*Case* 22.

Lateral neuroma of anterior crural.

November: Immediate relief of pain.

May, 1918: Voluntary twitching in quadriceps.

July: Patient can raise heel from ground with extended knee. Thigh muscles still weak and easily fatigued. No faradic response in quadriceps.

Summary.—Considerable improvement in 8 months.

C. IMPROVED CASES.

These comprise sutures of 4 ulnar nerves, 2 median, 1 musculospiral, and 1 posterior tibial. The first and second ulnar cases exemplify what has already been said about the comparative rate of recovery in this nerve. The third is interesting in the improvement which followed resection suture in a nerve apparently ligatured in error 2 years and 5 months previously. The only comment the last calls for is that a severe attack of cerebrospinal fever beginning within a week of operation did not hinder regeneration.

Case 23.—Pte. M., age 22. Small shrapnel wound of right upper arm 7·5 cm. above internal epicondyle, September, 1916.

December: Complete paralysis of all ulnar muscles below elbow with R.D., and corresponding sensory loss.

Operation, Dec.—Condition as in *Fig.* 368. Translation of nerve to front of elbow. Flexion of elbow. Resection. Suture. Cargile membrane.

March, 1917: Recovering protopathic sensation.

April 24: Further recovery of sensation. Formication has progressed 150 mm. below suture line, an average spread of 1·2 mm. per diem.

May 29: Voluntary power in flexor carpi ulnaris and ulnar half of flexor profundus digitorum.

Summary.—Improvement in 4 months.

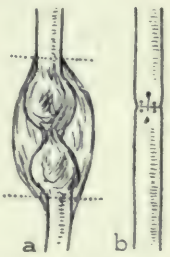


FIG. 368.—*Case* 23.

Complete division of ulnar. *a*. Before, *b*. After resection suture.

Case 24.—Pens. B. Wounded in middle of upper arm, September, 1915. Wounds suppurated.

Operation, June, 1916.—Ulnar completely divided, with two end bulbs. Resection. Suture.

January, 1917: Recovery of sensibility to pin-prick over ulnar side of ring and radial side of little finger. Voluntary power in flexor carpi ulnaris and flexor profundus digitorum. Bad degree of claw hand.

Summary.—Recovery of voluntary power in flexor carpi ulnaris and flexor profundus in 7 months.



FIG. 369.—*Case* 25.

Complete division of ulnar, possibly due to accidental ligature of nerve. *a*. Before, *b*. After resection suture.

Case 25.—Dvr. S., age 21. Cut his arm in August, 1914. No disability of the hand resulted. Hæmorrhage forty-eight hours after accident. Ligature passed on needle, without anæsthetic, and tied. This was immediately followed by pain and numbness in little finger.

December, 1916: Voluntary power in flexor carpi ulnaris and flexor profundus digitorum. Claw hand. Paralysis with R.D. of all small ulnar muscles, with corresponding sensory loss.

Operation, December.—Condition as in *Fig.* 369, suggesting that a ligature had been tied tightly round the nerve. Dislocation of nerve to front of elbow. Resection. Suture. Cargile membrane.

March, 1917: Recovery of sensibility to pin-prick over ulnar side of ring finger and radial side of little finger. Formication has progressed 80 mm. below suture line in 88 days, an average of 0·9 mm. per diem.

Summary.—Resection suture 2 years and 5 months after injury. Improvement after 3 months.

Case 26.—Pte. K., age 24. Bullet wound of right forearm, July, 1916.

Operation, April, 1917.—Complete section of ulnar (*Fig.* 370). Resection. Suture. Cargile membrane.

April 16: Onset of severe attack of cerebrospinal meningitis.

May 25: Pin-prick felt over radial border of little finger. Paralysis and R.D. in all muscles of hand. Formication 50 mm. below level of suture, an average of 1·1 mm. per diem.

Summary.—Improvement in 1 month.

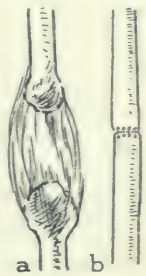


FIG. 370.—*Case* 26.

Complete division of ulnar, with large bulb on peripheral segment. *a*. Before, *b*. After resection suture.

Of the two median cases, one was a complete section in the forearm below the origin of the anterior interosseous, which improved within 4 months of suture and which calls for no further comment. The other not only exemplifies the internal topography of the median fibres in the forearm, but throws light on the fate of Cargile membrane.

Case 27.—Sgt. K., age 32. Shrapnel wounds of legs and forearms, October, 1916. Severe pain in middle finger, and to a less degree in index finger, of right hand. Paralysis with R.D. in opponens pollicis and abductor brevis pollicis. Pin-prick abolished on palmar surface of thumb.

Operation, Oct. 28.—Median exposed 7·5 cm. above wrist. Condition as in *Fig.* 371. Partial exsection and suture. Cargile membrane.

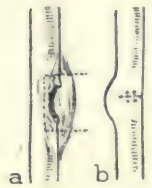


FIG. 371.—*Case* 27.

Lateral notch on radial side of median nerve. *a*. Before, *b*. After partial resection and suture.

January, 1917: Aneurysm of radial artery at right wrist developed.

Operation, January.—Artery tied above and below, and sac excised. Site of previous operation explored. Nerve still wrapped in Cargile membrane. Membrane lay snugly round the nerve, was grey in colour, and had lost its polished appearance. It felt soft and pliable instead of crinkly and brittle. Considerable young fibrous tissue had formed round the membrane, but nerve and membrane lay free from adhesions.

The Cargile membrane for three months had fulfilled the purpose of preventing adhesions to the nerve, ingrowth of scar tissue between the opposing raw surfaces of the partially divided nerve, and the escape of young nerve fibres.

Summary.—Cargile membrane still present after 3 months. Nerve free from adhesions.

The musculospiral case does not require comment.

Case 28.—Sgt. E., age 23. Shell wound of right arm 10 cm. above elbow, July, 1917. Paralysis of musculospiral muscles, with R.D.

Operation, January, 1918.—Neuroma with lateral notch (*Fig.* 372). Partial exsection and suture.

March: Formication 50 mm. below level of suture. No muscular recovery.

Summary.—Improvement in 2 months.

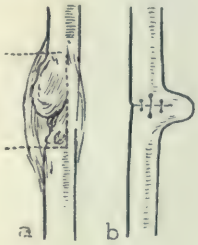


FIG. 372.—*Case* 28.

Lateral notch of musculospiral. *a*. Before, *b*. After partial exsection and suture.

The posterior tibial case throws light on the causation of pain in incomplete injuries of nerves. An artery firmly bound by scar to a nerve on which is a small lateral neuroma is a condition associated with pain. This fact has often been noted.

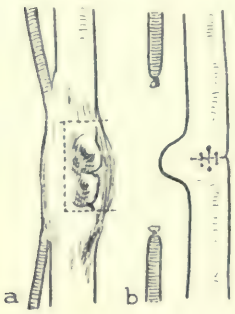


FIG. 373.—*Case* 29.

Lateral notch of posterior tibial. Artery bound down to nerve with scar tissue. *a*. Before, *b*. After excision of portion of artery and partial exsection and suture of nerve.

Case 29.—Pte. P., age 21. Through-and-through bullet wound of upper third of left leg, April, 1917.

May: Wounds healed. Severe pain in sole of foot. No loss of movements.

Operation, May 26.—Nerve embedded in scar tissue. Posterior tibial artery firmly bound to nerve by scar (*Fig.* 373). Artery tied above and below, and intervening portion excised. Partial exsection and suture of nerve.

July 21: Tenderness of sole of foot cured. No loss of movements. Formication 110 mm. below level of lesion—an average spread of 2 mm. per diem.

Summary.—Artery bound to nerve by scar associated with pain, relieved by operation.

D. NO-RESULT CASES.

These number 14. The length of time since operation varies from 24 months to 1 month. In the table of results there is no case of improvement at a date after operation later than 7 months. This lapse of time has therefore been arbitrarily chosen as a means of drawing a dividing line between cases which are actual failures and those which are only doubtful. Divided in this way, there are 5 failures and 9 doubtful cases.

i. **Failures.**—The study of these 5 cases throws interesting light on at least two causes of failure, and two of them provide food for reflection on the normal processes of regeneration, and on the best way of helping nature to carry these out.

The first case, one of ulnar destruction in the upper arm, illustrates the importance of a preliminary toilet by excising large adherent scars, either before or at the same time as the operation on the nerve, and of obtaining a covering of healthy skin either by some plastic procedure or by a preliminary pedicle graft.

Case 30.—Lieut. H., age 26. Large lacerated wound extending from axilla to elbow, and involving half the circumference of the arm on its postero-internal aspect, May, 1917.

July: Wound healed.

September: Complete paralysis with R.D. of all median and ulnar muscles below elbow, with corresponding sensory loss. Fingers very stiff. Later: Great pain in median sensory area. Flexor carpi radialis and flexor sublimis digitorum act feebly. Still complete paralysis and R.D. in ulnar.

Operation, Sept. 26.—Long incision from axilla to elbow just in front of scar. Scar raised from median and ulnar nerves. Neuroma of median. Neurolysis and capsulectomy. Ulnar found destroyed for 7·5 cm. Translation of nerve to front of elbow. Resection. Suture. Gap 10 cm. Flexion of elbow. Cargile membrane.

Oct. 6: Old scar broke down. Primary union of operation wound.

October: Cargile membrane pulled out of hole in scar, which refused to heal.

November: Wound healed.

May, 1918: Nearly complete recovery in median. No sign of recovery in ulnar.

Summary.—No recovery in ulnar 8 months after suture. Scar broke down over Cargile membrane. Recovery in median.

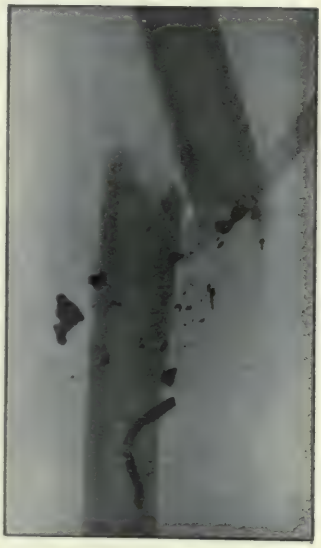


FIG. 374.—*Case* 31.

Compound fracture of humerus which complicated complete section of median.

In the following case, one of median and internal cutaneous division, there were several unfavourable conditions, all of which may have influenced the result.

Case 31.—Pte. P., age 18. Shrapnel wounds of right arm, with compound fracture of humerus 15 cm. above elbow, June, 1916 (*Fig.* 374). Complete paralysis of all muscles below the elbow, with sensory loss in median, ulnar, and internal cutaneous areas.

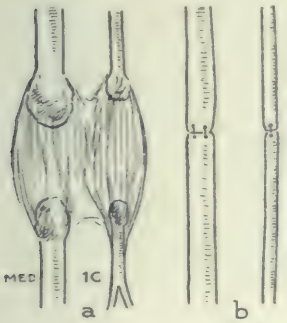


FIG. 375.—*Case* 31.

Complete section of median and internal cutaneous. *a*. Before. *b*. After resection suture.

October: The musculospiral and ulnar nerves have recovered. Complete paralysis with R.D. of median muscles. Sensory loss in median and internal cutaneous areas.

October, 1916, to May, 1917: Several sequestrotomies and removals of foreign bodies. Nerve condition unaltered. Hand cold and cyanosed. Radial pulse not palpable.

Operation, June, 1917.—Median and internal cutaneous found divided (*Fig.* 375). Resection. Suture. Cargile membrane.

January, 1918: No sign of recovery in median or internal cutaneous. No formication at level of suture.

Summary.—Obliteration of brachial artery. Suture of divided median and internal cutaneous 12 months after division. No recovery in 8 months.

The last two cases of failure are both sutures of the external division of the sciatic before it had left the sciatic trunk. In the one there was a deep lateral notch, in the other a hard neuroma.

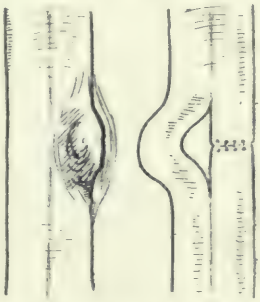


FIG. 376.—*Case* 32.

Lateral neuroma of external popliteal. Before and after exsection suture.

Case 32.—Pens. S., age 20. Shrapnel wound of right buttock, March 4, 1917. Foot dropped instantly.

October: Paralysis of external popliteal muscles with R.D., and sensory loss in external popliteal area. Formication at level of lesion.

Operation, October.—Neuroma of external division of sciatic at level of fold of buttock, adherent to scar and muscles (*Fig.* 376). Total exsection. Suture. Cargile membrane.

August, 1918: No recovery. Tinel's sign absent.

Summary.—No recovery 10 months after resection suture.

Case 33.—Pens. N., age 23. Bullet wound of right buttock, November, 1915. Drop foot. March, 1917: Complete paralysis with R.D. in external popliteal muscles, and corresponding sensory loss. Tinel's sign at level of lesion.

Operation, March.—External division of sciatic practically divided by deep lateral notch at level of fold of buttock, with well-defined bulb of upper segment (*Fig.* 377 *a*, *b*). Resection. Suture. Cargile membrane.

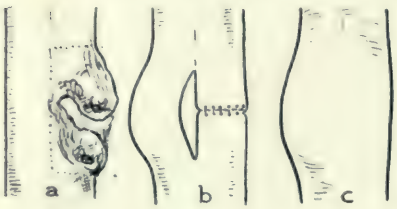


FIG. 377.—*Case* 33.

a. Lateral notch in external sciatic. *b*. After resection suture. *c*. Nineteen months later.

October, 1918: No sign of recovery. Tinel's sign absent.

Operation, October.—Nerve exposed. Considerable perineural scar tissue. Cargile membrane completely disappeared. No bleeding from surface of nerve on freeing from scar. Line of external division of sciatic continuous. No spindle or bulbs, and no trace of suture line. Bulge of internal sciatic still visible (*Fig.* 377 *c*). Incision closed. Whole of external division looked slightly yellow, and felt distinctly less firm than internal division. No conduction of faradic current.

Summary.—No recovery 19 months after suture. Exploration revealed apparently normal nerve with some perineural scar tissue. Disappearance of Cargile membrane.

These two cases are of considerable interest, the absence of recovery apparently depending on a cessation of growth of the axis cylinders from the central segment. In the first case, no special reason for this inability on the part of the nerve cells to reproduce axis cylinders suggests itself. In the second case, sixteen months elapsed between the dates of the wound and operation, and this length of time since injury might be held accountable. It is well known, however, that delayed suture has been successfully performed at a much later date than this.

Another possibility requires consideration. Each axis cylinder is, on the neurone theory, the process of a single nerve cell. When an axis cylinder is cut across, the distal portion degenerates, and there is also at first a retrograde degeneration of the central portion. The central portion then begins to regenerate by the formation of branching tendrils from the adjacent nodes two or three distant centrally from the cut (Ranvier, quoted by Cone[10]). Cone, in the article referred to, describing these regenerating cell processes, says, "They are varicose, bulbed at the end, frequently branch . . ." Each nerve cell, then, when its axis cylinder process has to regenerate, produces a number of feelers or tendrils which grow downwards, attracted may be by the sheaths of Schwann. Where there was one cell process there are now many, a kind of dendritic formation. What happens to these dendritic processes? Is it not reasonable to suppose that this is Nature's way of increasing the chance of at least one taking the correct path and becoming ultimately the adult axis cylinder in the distal segment? The fate of those which err on the way is unknown, but it is conceivable that they may ultimately shrivel or be withdrawn into the cell. In any case, the power of reproducing an axis cylinder, on the neurone theory, resides in a single cell, and means a considerable expenditure of regenerative vitality. The question which must be asked is: How often will a nerve cell repeat this regeneration of its axis-cylinder process? The frequent recoveries after resection sutures tell us that, in most individuals, nerve cells will repeat this process at least twice; but it is as unreasonable to suppose that it can be repeated an indefinite number of times as it is to suppose that an amœba might have its pseudopodia cut off an indefinite number of times and continue to live. Recovery after delayed suture, even in the absence of suppuration, is always slower and less complete than recovery after a primary suture. This is well established. Does this not indicate a regeneration fatigue on the part of the nerve cell, and may it not be that in certain individuals the nerve cells are only capable of this function once? This is the only explanation which suggests itself to the writer to account for the facts of the last case described. In this the nerve had apparently united perfectly; but the absence of all signs of recovery, including conduction of the electric current and Tinel's sign, proves that no axis cylinders had grown down from the central end; while the absence of any bulb or thickening above the suture

line, together with the absence of Tinel's sign at this level, suggests failure of the axis cylinders to reproduce themselves.

ii. **Doubtful Cases.**—The doubtful cases are 7 ulnar and 2 median sutures. One ulnar case was invalided five months after suture, and thereafter lost sight of. Another was transferred to Dartford and invalided to Australia after one month. A third was lost sight of two months after operation. The remaining 4 ulnar and 2 median cases concern four individuals still under observation, two of whom had a combined median and ulnar injury. Their case histories follow.

The first of them furnishes an example of an unusual nerve supply to the flexor longus pollicis, which retained voluntary power and faradic response though the median was completely divided in the lower third of the arm. Compensatory movements of flexion of wrist and fingers through the unparalyzed extensors were exceptionally developed.

Case 34.*—Pte. R., age 21. Bullet wound of lower third of right arm, August, 1917. Brachial artery divided. Complete median and ulnar paralysis.

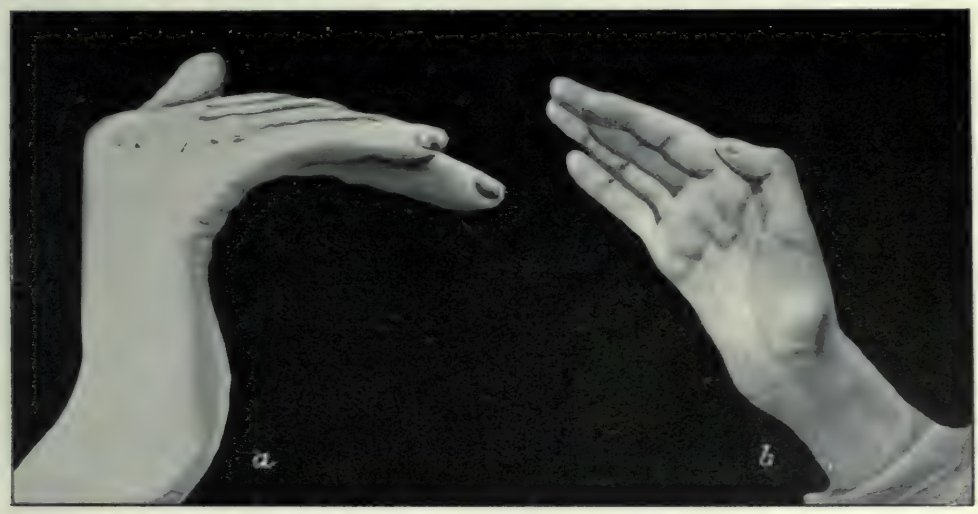


FIG. 378. *Case* 34. *a*. Shows flexion of finger in complete median and ulnar paralysis. *b*. Shows retention of voluntary power in flexor longus pollicis, though there was complete section of the median and ulnar in lower third of arm.

November: Wound healed.

June, 1918: Complete paralysis with R D. of all median and ulnar muscles below elbow, with exception of flexor longus pollicis, which retained voluntary power and faradic response (*Fig.* 378). Compensatory movements very noticeable. Flexion of wrist by extensor ossis metacarpi pollicis. Flexion of fingers by extending wrist and relaxing common extensors of fingers. Sensory loss in median, ulnar, and internal cutaneous areas. Tinel's sign at site of lesion only.

Operation, June.—Complete division of median, ulnar, and internal cutaneous nerves (*Fig* 379). Resection suture of median and ulnar. Lower end of internal cutaneous not found.

July: No change.

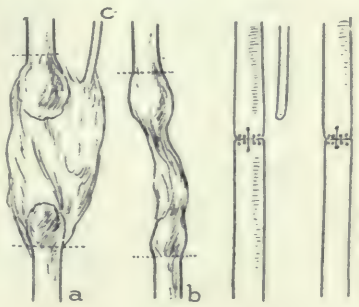


FIG. 379.—*Case* 34.

Complete section of median, ulnar, and internal cutaneous in lower third of forearm. Before and after resection suture of median and ulnar; lower end of internal cutaneous not found. *a*. Median, *b*. Ulnar, *c*. Upper end of internal cutaneous.

Summary.—Doubtful result. Case illustrates compensatory movements of unparalyzed muscles, and abnormal nerve-supply to flexor longus pollicis.

The next case, of similar type, deserves recording as an example of the spontaneous union of the upper segment of the median with the lower segment of the ulnar.

Case 35*. Lieut. G. Bullet wound of right shoulder, entrance outer side, bullet passing across axilla and being retained in chest, August, 1917.

January, 1918: Wounds healed.

June: Complete paralysis with R.D. of all muscles below elbow supplied by median and ulnar, and corresponding sensory loss. Compensatory movements of extensors well developed. Tinel's sign in ulnar nerve at bend of elbow.

Operation, June.—Both nerves completely divided, but upper segment of median partially united to lower end of ulnar (*Fig.* 380). Resection. Suture.

July: No change.

Summary.—Doubtful result. Union of upper segment of median with lower segment of ulnar.

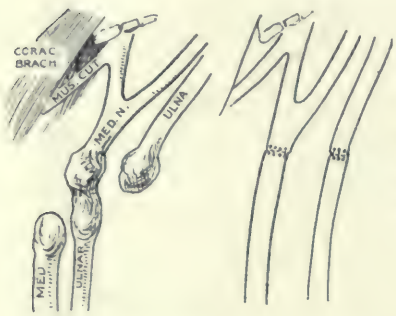


FIG. 380.—*Case* 35.

Complete section of ulnar and median with vicious union of upper segment of median with lower segment of ulnar.

The succeeding story relates an anatomical anomaly.

Case 36.*—Pte. K., age 42. Shrapnel wound of left arm above epicondyle, March, 1918.

July: Wound healed. Scar adherent to bone and nerve in epitrochlear groove. Formication at level of injury. Voluntary power and faradic response in flexor carpi ulnaris and first dorsal interosseous. Remaining ulnar muscles paralyzed, with R.D. Sensory loss confined to little finger and ulnar border of hand.

Operation, Aug.—Ulnar completely destroyed for 3·6 cm. above elbow, with bulbs. Just above upper bulb a branch from nerve was found passing in front of epicondyle (*Fig.* 381). Direct faradic stimulation of branch produced contraction of flexor carpi ulnaris.

September: No change.

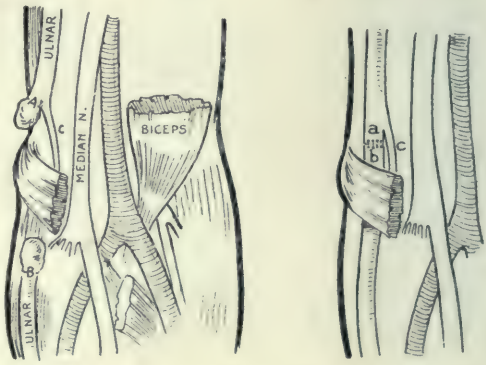


FIG. 381.—*Case* 36.

Complete division of ulnar in the region of elbow, showing abnormal branch *c*, passing in front of epicondyle.

Summary.—Complete section of ulnar behind epicondyle. Branch to flexor carpi ulnaris passing in front of epicondyle. Nerve supply to first dorsal interosseous probably from median.

The fourth doubtful case requires no comment.

Case 37.*—Rfm. F., age 31. Shell wound of middle of right forearm, August, 1917.

January, 1918: Wounds healed.

April: Complete paralysis with R.D. of small ulnar muscles of hand with clawing, and sensory loss of ulnar area.

Operation, April.—Complete section. Resection. Suture.

May: No change.

3. NEUROLYSES.

Tinel[11] thus describes a neurolysis or liberation: "La libération consiste essentiellement dans la dissection du nerf et dans l'ablation des causes de compression, cal osseux, gangre fibreuse, ou bride cicatricielle." He lays down the dictum, "Pour tous les cas, douteux, il faut se rappeler qu'une bonne et franche suture vaut beaucoup mieux qu'une mauvaise libération." Delagenière, quoting Tinel's opinion says, "It is

*Since working out the statistical part of this paper, *Cases* 34 to 37 show definite signs of improvement.

very difficult to form an opinion of the value of nerve liberations. We have done relatively few, because it has seemed to us that they do not generally give better results than abstention."

A discussion on the value of neurolysis must begin with a succinct statement of the

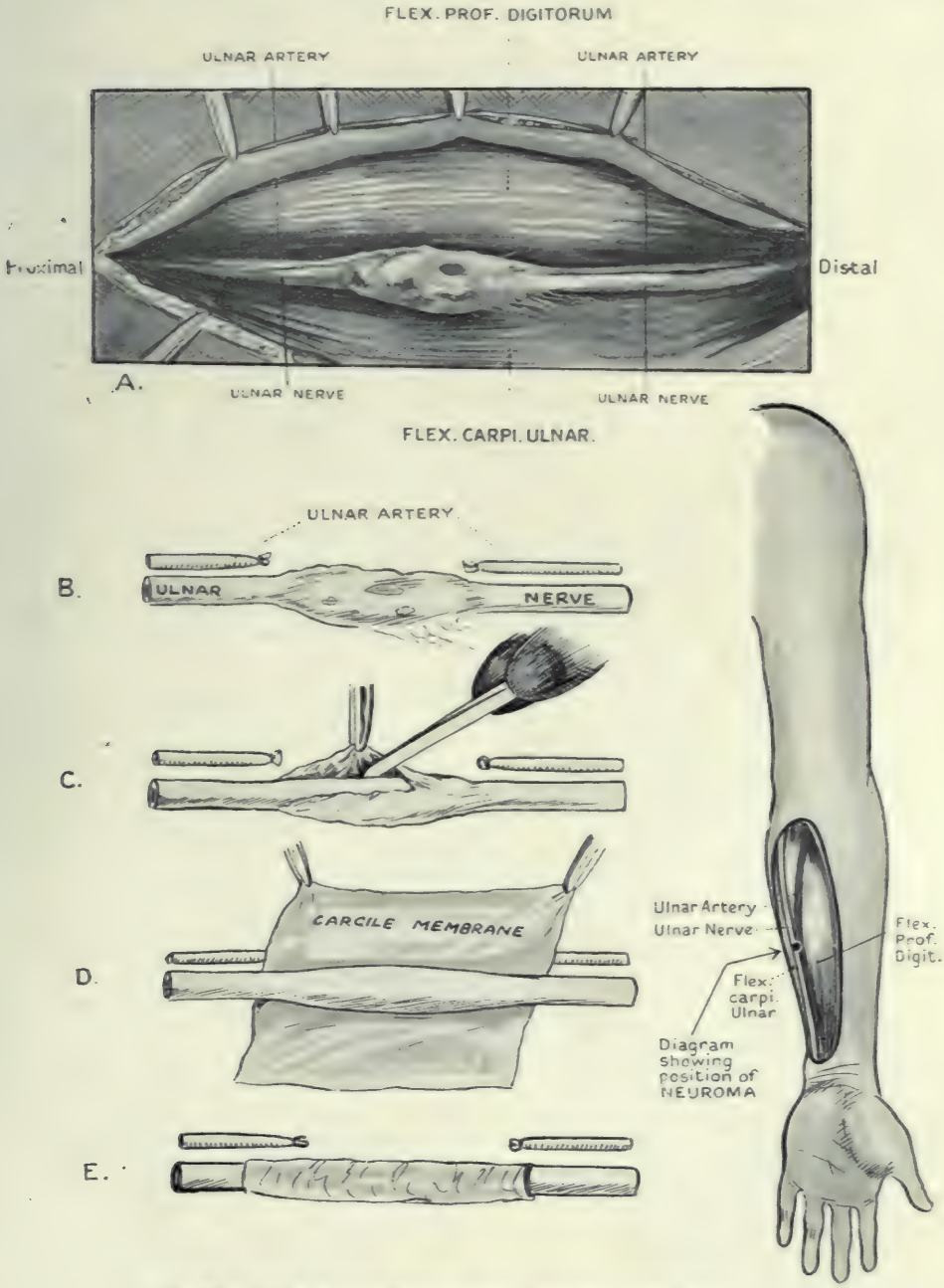


FIG. 382. Details of neurolysis capsulectomy, drawn from an actual case.

exact details of the operation performed, must continue with a clear understanding of the type of case in which it is used and of the results which it is hoped to obtain, and must be settled by an appeal to actual case-histories, comparing the results with those following other surgical procedures and those following abstention.

The operation performed consists in dissecting out the nerve, and removing all causes of compression such as bony callus, fibrous tissue, and adhesions. The thickened portion of the sheath of the nerve must also be removed. This latter procedure is hereafter called a 'capsulectomy.' The details are shown in *Fig.* 382, drawn from an actual operation.

After a capsulectomy, the next and possibly the most important step is to protect the delicate nerve spindle which has been stripped of its sheath, and to prevent its compression by fresh adhesions or the contraction of new scar tissue. The natural bed for a nerve is the intramuscular space, and in every case this space is the ideal bed, and should be sought after. In the forearm, where there are many contiguous muscle bellies, and in the upper arm, where the space between the biceps and brachialis anticus is available, the plan can usually be adopted of laying the nerve in healthy tissue between muscles.

In some situations—as, for example, the musculospiral in the groove—the attainment of a natural bed for the nerve is impossible. The writer in these cases has generally employed a covering of Cargile membrane, around which the adjacent muscles are neatly stitched so as to prevent it becoming unrolled. Cargile membrane is sold in different thicknesses, and it is a matter of some importance to choose the finer varieties, in view of Souttar's[12] observation on the exploration of old nerve sutures protected in this way, that he found the membrane lying in the tissues as a loose foreign body. When used in the way indicated, no harm has been observed to follow its employment. The writer has explored four nerves protected with Cargile membrane, at intervals of 3, 4, 7, and 19 months (*Cases* 5, 7, 26, and 32). From them the conclusion is drawn that the membrane is absorbed in under six months, during which time it fulfils its purpose in protecting the nerve from compression and adhesions. Cone observes that Cargile membrane is impervious to nerves, and it may therefore be also expected to prevent the straying of nerve fibres.

The plan adopted by some workers of making a bed for the nerve by a small longitudinal incision into an adjacent muscle belly is regarded with diffidence, on account of the fact so often noticed of the tendency of cut muscles to adhere to injured nerves.

Types of Cases in which Neurolysis and Capsulectomy have been Performed.—The cases in which this operation has been performed are divided into four groups : (*a*) Those with complete physiological interruption ; (*b*) Those with incomplete physiological interruption ; (*c*) Those where pain has been the indication for interference, with or without complete or incomplete physiological interruption ; (*d*) Those associated with aneurysms and brachial plexus injuries.

The writer believes that the reason for Tinel's remarks quoted at the beginning of this section—which have also been echoed by writers in this country—has been an unjustified expectation of what the operation is capable of doing. Neurolysis, in cases where compression by extraneural conditions is the only factor involved, is followed by an extremely rapid recovery occurring within a few days. Because these striking results have not followed the operation in other cases where other factors are involved, the operation has been too hastily abandoned in favour of resection suture. Among the unoperated cases are several examples of spontaneous regeneration occurring along the same lines as after a primary suture of a completely divided nerve. In such a case the operation of neurolysis cannot be expected to produce a cure in a few days. At most it could hasten and render such a recovery more complete. Regeneration is a slow and tedious affair after all sutures.

Realizing then that neurolysis, in some cases combined with a capsulectomy, cannot be expected to produce a rapid cure except in cases of pure extraneural compression, the following questions remain to be answered by an appeal to the series of cases in which

this operation has been performed: (1) Can a neurolysis remove the conditions which inhibit regeneration in a nerve anatomically continuous but physiologically interrupted, with degeneration in the segment below the injury? (2) Can a neurolysis hasten recovery in a nerve anatomically continuous which has been physiologically interrupted, but which is regenerating in the segment below the injury? (3) Of what value is neurolysis in cases where pain is the chief symptom to be relieved?

A. CASES OF COMPLETE PHYSIOLOGICAL DIVISION.

Out of 39 cases undergoing neurolysis, 17 were undertaken for complete physiological interruption of the nerve, without loss of anatomical continuity, but with no sign of regeneration in the segment below the injury. The results are shown in *Table VI.*

Table VI.—Neurolysis and Capsulectomy in 17 Cases of Complete Physiological Interruption.

	Recoveries	Considerable Improvement	Improvement
Number of cases	8	6	3
Average time since wound	17 months	11 months	8 months
Average time since operation	12 ,,	8 ,,	3 ,,
Longest ,, ,, ,,	24 ,,	13 ,,	3 ,,
Shortest ,, ,, ,,	6 ,,	1 ,,	1 ,,

i. **Recovered Cases.**—These comprise 2 ulnar, 1 musculospiral, 1 musculocutaneous, 1 posterior interosseous, 1 sciatic, 1 posterior tibial, and 1 brachial plexus injury. The brachial plexus injury, forming with others of the same nature a special group, will be described in a later section of the paper. The case histories follow.

Case 38.—Pte. F., age 24. Through-and-through wound of flexor aspect of right forearm 5 cm. above wrist, August, 1916.

September: Wounds healed.

December: Claw hand. Complete paralysis with R.D. of ulnar muscles of hand. Complete ulnar sensory loss.

Operation.—Neuroma (*Fig.* 383). Neurolysis. Capsulectomy. Cargile membrane.

November, 1917: Complete return of protopathic sensation. Voluntary power in small muscles of hand.

Summary.—Recovery in 11 months.

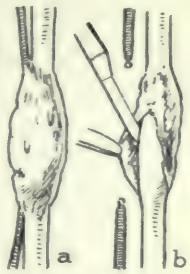


Fig. 383.—*Case* 38.

a. Spindle neuroma of ulna. *b.* Neurolysis capsulectomy.

Case 39.—Pte. P., age 20. Shell wound of lower third and middle of right arm, with compound fracture of humerus, February, 1916.

April: Wrist-drop and paralysis of musculospiral. Great pain in median area. Total paralysis of ulnar. Hand useless.

May: Fracture united. Early recovery of musculospiral. Median and ulnar condition unchanged.

October: Wound healed. Continued improvement in musculospiral. Median and ulnar paralysis.

January, 1917: Musculospiral recovered. Hyperalgesia in median. Anæsthesia in ulnar. Median muscles have voluntary power, but are very wasted. Ulnar muscles have no voluntary power and complete R.D.

Operation, Jan. 16.—Incision through very wide scar above elbow. Ulnar thickened, with very hard neuroma. Median involved in dense scar. Neurolysis and capsulectomy of median and ulnar. Cargile membrane. Wound healed by primary union.

March: Scar broke down. Cargile membrane expelled.

April: Scar sound.

Aug. 24: Steady improvement. Formication at level 5 cm. above wrist—250 mm. in 220 days.

January, 1918: Voluntary power in all muscles of median and ulnar. Complete return of sensibility to pin-prick. Hand still tender.

Summary.—Recovery in 12 months. Cargile membrane expelled.

The next case, that of the musculospiral, illustrates a condition noticed by Renfrew White,[13] where a division of this nerve may produce an area of sensory loss on the dorsum of the hand in which protopathic loss overlaps and extends beyond the area of epicritic loss.

Case 40.—Pte. S., age 20. Shell wound of lower third of right arm, with fracture of humerus, January, 1917.

April: Wound healed. Fracture united.

July: Complete paralysis and R.D. in musculospiral below elbow. Sensation as in *Fig.* 384.

Operation, July.—Hard neuroma, involving 7·5 cm. of nerve, freed from scar (*Fig.* 385). No conduction of faradism above or below injury. Resection considered necessary, but abandoned on account of the wide gap which would have been left. Capsulectomy. New path for nerve in brachialis anticus. Cargile membrane.



FIG. 384.—*Case* 40.

Extent of loss of sensation to *a*. Pin-prick. *b*. Cotton-wool.



FIG. 385.—*Case* 40.

Neuroma, with complete physiological interruption, of musculospiral. Before and after neurolysis capsulectomy.

January, 1918: Complete return of sensation both to pin-prick and brush. Voluntary flicker in extensors of wrist.

July: Complete recovery in all muscles.

Summary.—Recovery after 12 months.

Case 41.—Pte. B., age 25. Bullet wound of left shoulder, January, 1917.

April: Complete musculocutaneous paralysis, with R.D. of biceps, coracobrachialis, and brachialis anticus.

Operation.—Nerve freed from scar. Capsulectomy of neuroma. Free flap of fat and fascia wrapped round nerve.

October: Upper arm still smaller than right. Voluntary power and faradic response in biceps. Voluntary power in brachialis anticus.

Summary.—Recovery in six months.

Case 42.—Pte. T., age 22. Bullet wound of right forearm, with compound fracture of neck of radius and injury to posterior interosseous, August, 1915.

November: Complete paralysis with R.D. of wrist, finger, and thumb extensors.

Operation, November.—Nerve freed from callus. Neuroma on nerve just above level of division into muscular branches.

February, 1916: No recovery. Invalided.

March, 1918 (by examination): Complete recovery of extensors of wrist and fingers. No faradic response, but brisk galvanic, without polar changes.

Summary.—Recovery within 2 years.

Case 43.—Pte. T., age 21. Bullet wound of left buttock, Sept. 25, 1916.

November: Wound healed.

December: Complete paralysis of all muscles below knee with R.D., and sensory loss in areas of internal and external popliteal.

Operation, December.—Nerve freed from dense scar and wrapped in Cargile membrane. No apparent injury to nerve.

January, 1917: Voluntary flicker in tibialis anticus. No other change. Invalided.

December (extract from letter): "My leg has made good progress—the muscles have developed and are nearly normal again, the calf muscle is also making rapid progress. I have a fair amount of movement in my foot, but there is still a little drop. I manage to get about without my sticks or the splint, and am able to attend my work, which is engineering."

Summary.—Recovery in 11 months.

Case 44.—Pte. B., age 26. Shell wound of right leg, lower third, July 15, 1916.

December: Anæsthesia of sole of foot and paralysis of small foot muscles, with R.D. Percussion over scar causes pins-and-needles in foot.

Operation, December.—Neuroma of nerve freed from scar. Capsulectomy.
May, 1917: Sensation recovering.
August: Faradic response from small muscles of foot. Sensation recovered.
Summary.—Recovery in 9 months.

ii. **Considerably Improved Cases.**—This group is concerned with 2 median, 1 ulnar, 1 musculospiral, 1 sciatic, and 1 brachial plexus injury. With the exception of the brachial plexus lesion, the cases are given below.

Case 45.—Pte. S., age 34. Through-and-through bullet wound of front of left elbow, with fracture of neck of radius, April, 1917.
July: Complete paralysis of all median muscles with R.D., and complete sensory loss.
Operation, July 21.—Nerve and its muscular branches freed with great difficulty from dense scar. Superficial head of pronator radii teres divided. Large hard neuroma. Capsulectomy. New intermuscular path provided.
October: Hand cyanotic. Some recovery of pin-prick sensation.
April, 1918: Voluntary power in flexors. None in opponens pollicis. Pin-prick everywhere felt.
August: Voluntary power in all median muscles, including opponens pollicis and abductor brevis pollicis, but fingers still painful and stiff. Hand still cyanotic.
Summary.—Considerable improvement in 13 months.

Case 46.—Lieut. H., age 30. (See *Case* 29.)

Case 47.—A.-B. C., age 21. Through-and-through bullet wound of lower third of upper arm, October, 1917.
April, 1918: Paralysis of ulnar muscles below elbow with R.D., and complete sensory loss.
Operation, May 9.—Neuroma of ulnar where nerve passes through internal intermuscular septum. No faradic conduction. Neurolysis. Capsulectomy. New intermuscular bed provided.
Aug. 9: Tinel's sign. Average spread, 1·5 mm. per diem. Voluntary power in flexor carpi ulnaris and whole of flexor profundus digitorum. Clawing of little and ring fingers increased. Recovery of protopathic sensation.
Summary. — Considerable improvement in 5 months.

Case 48.—C.-S.-M. H., age 28. Bullet wound of upper third of left arm, with compound fracture of humerus, March, 1918.
July: Complete paralysis of all musculospiral muscles, with R.D.
Operation, July.—Very hard spindle in course of nerve involved in callus (*Fig.* 386). Faint faradic response in radial extensors to strong current. None in other muscles. Neurolysis. Capsulectomy.
September: Voluntary power in radial extensors. Still R.D. of all musculospiral muscles.
October: Weak voluntary power in common extensors. Good voluntary power in radial and thumb extensors. Still no faradic response.
Summary. — Considerable improvement in 4 months.

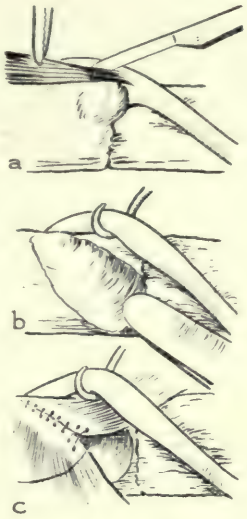


FIG. 386.—*Case* 48. *a*. Neuroma of musculospiral involved in fracture. *b*. Nerve freed. New groove cut in bone. *c*. Groove lined with muscle forming bed for nerve.

Case 49.—Pte. S., age 28. Shrapnel wound of left buttock, July, 1917. Foot drop. Severe pain in left foot.
August: Complete paralysis with R.D. of external popliteal muscles, and corresponding sensory loss. Severe pain and tenderness of sole of foot.
Operation, August.—Gluteus maximus split, pyriformis retracted upwards. Shrapnel ball removed from hole in ilium. Several small bone fragments removed from nerve. Neuroma of outer side of nerve. Capsulectomy. Pedunculated flap of fat inserted between bone and nerve.
October: Less pain in foot.
February, 1918: Sensation recovered except on dorsum of three outer toes.
June: Weak voluntary power in all muscles below knee. Faradic response present.
Summary.—Considerable improvement in 11 months.

iii. **Improved Cases.**—These are 1 median, 1 sciatic, and 1 peroneal injury.

Case 50.—Pte. P., age 31. Through-and-through wound of upper third of right forearm, January, 1917. Six days after wound severe secondary hæmorrhage. Proximal ligature of brachial.

June: Severe ischæmic contracture of flexors. Complete sensory loss in median area, with paralysis of opponens pollicis and abductor brevis pollicis, with R.D.
Operation.—Hard neuroma freed from scar tissue. Capsulectomy. Cargile membrane.
September: Partial recovery of protopathic sensation.
Summary.—Improvement in 3 months.

The sciatic case is an interesting example of the bad result afforded by a protective sleeve of fascia lata. This case was under the care of Major Guilding, who performed three operations on the case, and kindly allowed the writer to assist him at the third.

Case 51.—Pte. M., age 20. Bullet wound of middle of right thigh, July, 1916.
September: Drop foot. Complete paralysis of external popliteal, with sensory loss.
First Operation.—Nerve simply liberated from scar tissue.
November: No recovery.
Second Operation.—Nerve wrapped in sleeve of fascia lata.
December: Paralysis of calf muscles, with sensory loss in sole of foot, gradually supervened.
February, 1917: No change.
Third Operation.—A spindle-shaped neuroma, 7·5 cm. long, of whole sciatic trunk, involved in dense scar and adherent to surrounding muscles, was exposed and freed. The fascia lata was found to be incorporated with the sheath of the nerve, forming a dense thick capsule. One portion of the fascia retained its shiny surface, and was tightly constricting the internal division of the nerve. After a capsulectomy had been done, the surface of the spindle was covered with small bleeding spots where there had been an ingrowth of small blood-vessels from the surrounding adhesions. Bleeding checked with 1–1000 adrenalin. Cargile membrane.
June: Recovery of sensation in sole of foot. Voluntary power in calf muscles and peronei.
Summary.—Simple neurolysis gave no result in 3 months. Second neurolysis and protection with free sleeve of fascia lata was followed by an aggravation of the symptoms. Third neurolysis combined with capsulectomy and Cargile-membrane protection gave improvement in 4 months.

This case raises two questions: (1) What is the cause of the undoubted tendency of cut muscle to adhere to an injured nerve? (2) Why does a fascial sleeve afford no protection? The answer is given in Cone's researches, where he found that nerves grow in both fascia lata and muscle, and better in the former. After a suture, when the sheath has been properly approximated, a fascial sleeve may possibly protect a nerve from pressure of scar. That it may do no harm is seen in *Case* 9. In lacerated nerves where the sheath is torn, the young nerves stray, grow through the fascia into the muscles, and form a solid growth of nerve, muscle, and fibrous tissue, so that as a protection after a capsulectomy it is contra-indicated.

Case 52.—Lieut. F., age 19. Aeroplane accident, January, 1918. Fracture of right femur and left tibia. Left foot-drop. *X* ray showed external tuberosity of left tibia completely split off.
June: Complete paralysis with R.D. of external popliteal muscles, with complete sensory loss.
Operation.—Nerve found adherent to head of fibula, with flattened neuroma in its course. Neurolysis. Capsulectomy. New intermuscular path made for nerve.
July: Tinel's sign 30 mm. below level of injury.
Summary.—Improvement in 1 month.

The remaining 22 operations of neurolysis were performed either for incomplete physio'ogical divisions which were not recovering satisfactorily, or for the relief of pain (including cases associated with aneurysms and brachial plexus injuries). The tabulated results are shown in *Table VII.*

Table VII.—22 Cases of Neurolysis for Incomplete Physiological Division or for Relief of Pain.

Recovery	Considerable Improvement	Improvement
14	6	2

B. CASES OF INCOMPLETE PHYSIOLOGICAL DIVISION.

Of a group of 4 incomplete divisions or incomplete recoveries (one involving two nerves), the first is yet another example of a neurolysis capsulectomy. The second and third illustrate rapid improvement in nearly-recovered cases from a simple freeing, showing that the mobility of the nerve is of great importance to the completeness of a recovery. This suggests that massage and other means directed towards mobilization of the nerve at the level of a suture should be part of the post-operative treatment. The fourth—an early case in the series —is an example of a pithiatic condition (unrecognized at the time) combined with an organic lesion.

Case 53.—Sgt. W., age 27. Bullet wound of right forearm, May, 1915.

May, 1916: Admitted under writer. Weak voluntary power in opponens pollicis. Sensation normal on ring and middle finger. Pin-prick not felt over index finger and thumb.

Operation.—Nerve freed from scar tissue and adherent muscle. Spindle-shaped neuroma 2·5 cm. long in course of nerve. Capsulectomy. Cargile membrane.

Aug. 16: Good opposition of thumb. Recovery of protopathic sensation.

Patient returned to the army and obtained a commission.

October, 1918 (by examination): Hand perfect except compass test over palmar surface of index finger.

Summary.—Recovered. Compass test defective after 3 years.

Case 54.—Pte. W. Bullet wound of middle of right upper arm, June, 1916. Weakness in opponens pollicis, with blunting of sensation in median area.

Operation, July: Simple neurolysis of soft neuroma. New intermuscular bed made for nerve.

October: Recovered. Discharged to duty.

Case 55.—Pens. C. Through-and-through bullet wound of left forearm, May, 1915.

March, 1916: Admitted for inability to flex index and middle fingers. Hyperæsthesia of median nerve. Skin thin and glossy. Nails recurved. Pin-prick felt everywhere. Brush sensation patchy.

Operation.—Large soft neuroma simply freed from adhesions to scar and muscles.

Two days later, index and middle fingers could be flexed.

October, 1916: Recovered. Working as postal clerk.

Case 56.—Pens. R., age 33. Bullet wound of lower third of right arm, March, 1915.

October, 1916: Admitted. Stated that he had been unable to flex fingers or oppose thumb for six months after injury. Pithiatic condition. Nails recurved. Skin pink and sweating. No muscular wasting or paralysis, but unable to flex fingers. Coarse tremor when flexion of fingers is attempted, with synergic contraction of extensors. Sensation normal.



FIG. 387.—*Case* 56. *a*. Spindle neuroma of median, and small lateral notch of ulnar, associated with pithiatic condition. *b*. After neurolysis.

Operation, November.—Mulberry-like neuroma of median, and lateral neuroma of ulnar, freed from scar tissue and adherent muscles (*Fig.* 387).

March, 1917: Sweating cured. Functional tremor and inability to flex fingers unaltered.

C. PAINFUL LESIONS.

Pain has occurred in varying degrees and under various circumstances. The extreme form known as causalgia has been noted in 5 cases, affecting the median twice, and the sciatic trunk, the external popliteal, and the anterior crural once each. These cases form a distinct clinical group, and are characterized in brief by the intense paroxysmal and burning pain, by the atrophy of the limb below the lesion, by the weakness of the muscles without any definite paralysis, by the harsh dry skin and absence of perspiration, and by the peculiar mental condition which develops. Benisty[14] says, "Patients so affected are dismal, pale, and waxen. . . . They escape from noise, avoid society, and remain curled up in their beds or on a sofa in peculiar attitudes of defence." They are martyrs to insomnia, and lose their appetites. Two of the five cases threatened suicide. The group stands out in contrast with the less severe form,

in which pain, though oftentimes very severe, is not associated with any change in the patient's mentality, and in which the skin is pink, soft, and bathed in sweat.

Of three belonging to the series, two (*Cases* 15 and 22), one median and one anterior crural, have already been described; the remaining one is a particularly interesting example of an osseous formation in the sheath of the sciatic trunk, analogous to the so-called traumatic myositis ossificans. The other two cases described below, not included in the statistical tables, are given because of their intrinsic interest.

Case 57.—Pte. M., age 24. Through-and-through bullet wound of upper right thigh, October, 1916. Entrance wound left side of scrotum. Exit behind and level with tip of great trochanter.

January, 1917: Patient suffers intense burning pain, so severe at times that he is found crying. He will not leave his bed, but remains curled up under the bed-clothes. No anæsthesia. No paralysis. Much wasting of leg. Skin of foot harsh and dry.

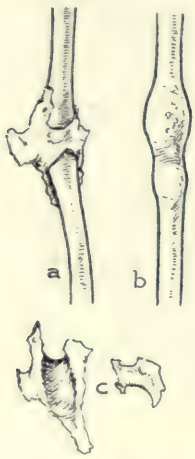


FIG. 388.—*Case* 57.

a. Neuroma of sciatic, with new bone formation in capsule. *b*. After neurolysis capsulectomy. *c*. Collar of bone removed from capsule.

Operation.—Bony collar found in sheath of sciatic trunk. The condition was that of a spindle-shaped neuroma with osseous formation in the capsule (*Fig.* 388 *a*). Neurolysis. Capsulectomy. Cargile membrane. Surface of the nerve compressed, grooved, and pitted by the bone. After removal, the pieces of bone fitted together like a jig-saw puzzle into a collar through which the nerve passed (*Fig.* 388 *c*).

A study of the position of the entrance and exit wounds suggested that the bullet grazed the tuber ischii and carried with it some osteoblasts which were deposited around a laceration of the nerve.

May: Improved. Sleeps well. *X* ray shows no recurrence.

November: Cured. Can walk about all day in boots.

December: Discharged to Command Depôt.

Summary.—New bone formation in capsule of spindle neuroma, causing pain—relieved by operation.

The next case is an example of the failure to cure the condition (causalgia) by Sicard's plan of injecting the nerve with 60 per cent alcohol—followed by immediate relief after exsection suture.

The writer views the injection of nerve trunks with some diffidence. Several cases have now been recorded in which severe trophic ulceration has been produced; and he has heard of one case in which 15 cm. of a median nerve were totally destroyed by this procedure. In addition, he has now under his observation two cases in which the internal popliteal nerve was injected with 60 per cent alcohol for pain associated with tonic spasm of the calf muscles, in which total paralysis with R.D. resulted and persisted for over six months.

Case 58.—Pte. D., age 24. Shrapnel wound of left thigh, July, 1917.

August, 1918: Shrapnel ball removed from side of knee in France.

On admission, patient was morose and silent. Complained of severe pain in left foot. Weakness but no paralysis in anterior tibial and peroneal muscles.

September: Nerve injected with 60 per cent alcohol.

October: No relief from pain.

Operation.—Small lateral neuroma of external popliteal. Affected segment exsected. Suture. Immediate relief of pain.

October, 1918: Sensibility to pin-prick recovered. Voluntary power and faradic response in anterior tibial and peroneal muscles.

Summary.—Causalgia of external popliteal. No relief after injection of 60 per cent alcohol. Cured by exsection of affected segment, with suture.

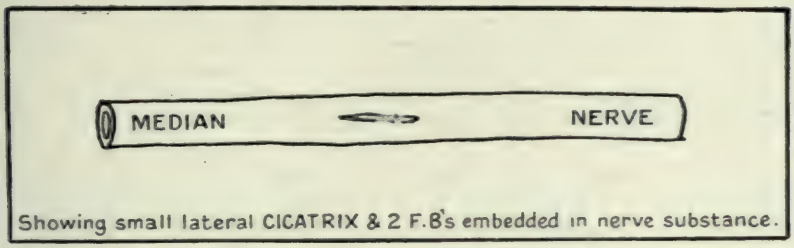
The last case is an example of causalgia resulting from a minute injury of the nerve by two tiny metal fragments some distance away from the wound.

Case 59.—Gnr. H., age 31. Shell wound of left forearm, May, 1918.

June: Very severe median causalgia of left hand.

Operation.— Scar excised. No injury to median nerve in immediate region of wound. Nerve found adherent to muscles two inches below wound. Adhesions separated. Small lateral neuroma. Two tiny metallic fragments found and removed from surface of neuroma (*Fig.* 389). Nerve injected with 60 per cent alcohol on proximal side.

October: Incomplete relief of pain.



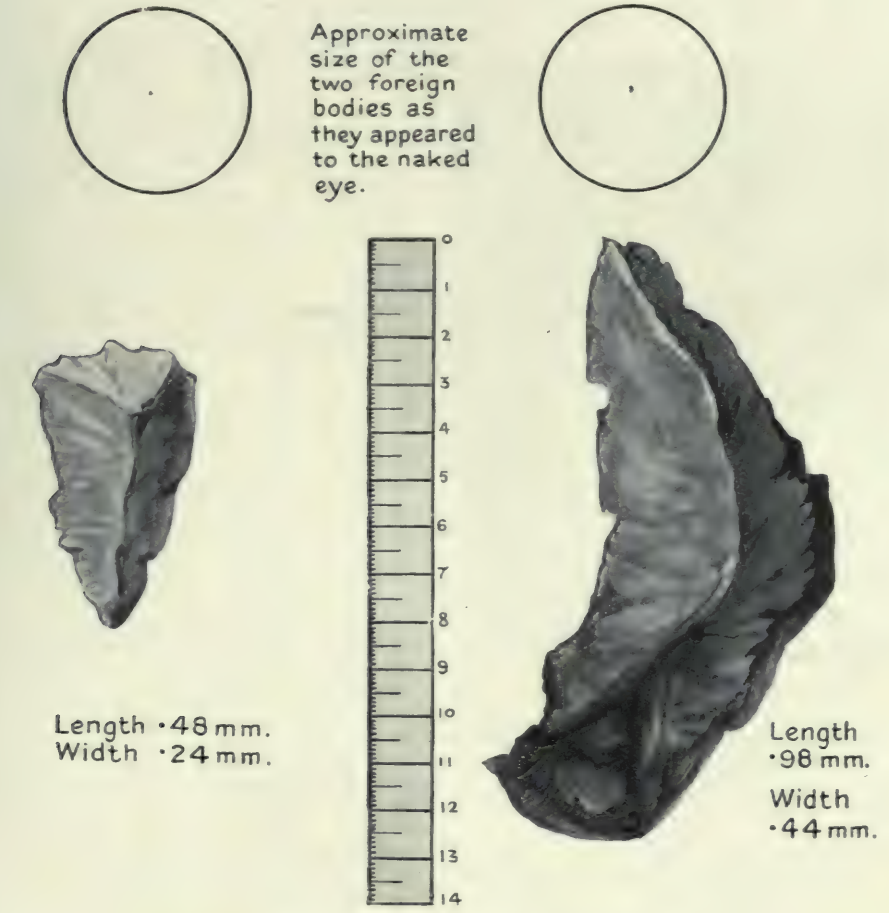


FIG. 389. *Case* 59. Tiny fragments buried in median, producing severe causalgia.

In all of the preceding cases a definite injury of a main trunk has been discovered, in four instances associated with the formation of a small lateral neuroma or lateral bulb. Of these four, in three the pain was immediately relieved by exsection of the affected segment. Why is it that this type of lesion produces a causalgia in some, pain of moderate severity in others, and no pain at all in the remainder? Marinesco and Corner[15] have explained the pain in amputation neuromata by the irritation of an infective inflammation. Possibly the answer to the question is to be found in the presence or absence of inflammation; or it may be that the inflammatory reaction to different groups of organisms provides the true solution. In this connection a study of the bacterial flora of infected nerve wounds would be of considerable interest.

With regard to pain of moderate severity, a neurolysis revealed in 9 cases a small lateral neuroma in the course of the nerve. In all, the operation was followed by some relief for a few days, but, in all, the pain recurred to a greater or lesser extent, and after some months disappeared slowly and spontaneously. The nerves involved were the median in 4 cases, the internal cutaneous in 1, and the sciatic or its branches in 4. The record of one will serve to illustrate them all.



FIG. 390.—*Case* 61. Foreign body causing pain in sciatic.

Case 60.—Pte. G., age 24. Bullet wound of upper third of left arm, September, 1915.

November: Much pain in median area. No paralysis or anæsthesia. Skin of hand pink and sweating. Nails tapering and curved. A pin-prick produces a red spot which remains for two days.

Operation.—Median freed from scar tissue. Nerve swollen and blue-grey, with spots of dark purple colour. On its inner side a small neuroma adherent to the biceps muscle.

December: Relief followed operation for a few days, but pain and tenderness have returned. Skin still glossy and sweating.

May, 1916: Some improvement, but still pain. Vasomotor disturbance still evident.

August: Considerable improvement.

November: Cured.

Summary.—Immediate relief, followed by recurrence of pain, after neurolysis. Gradual spontaneous cure.

Only one case of pain has been seen which could be attributed to the sole factor of irritation by a foreign body.

Case 61.—Pte. C., age 33. Shrapnel wound of left buttock, April, 1917. Entrance left buttock 6·2 cm. behind great trochanter. Severe pain in foot when walking, sitting, or lying down. No paralysis or anæsthesia. *X* ray showed foreign body in neighbourhood of sciatic (*Fig.* 390).

Operation.—Gluteus maximus split. Foreign body found embedded in scar just behind sciatic. Removed.

Immediate and permanent relief of pain.

D. CASES ASSOCIATED WITH ANEURYSMS AND BRACHIAL PLEXUS INJURIES.

Five cases remain to be recorded where a neurolysis was performed for the relief of pain and pressure symptoms resulting from the presence of an aneurysm.

One of these, a case of partial median and ulnar paralysis, associated with severe pain produced by the pressure of a circumscribed traumatic aneurysm of the brachial

in the upper third of the arm, has already been recorded by the writer in this Journal.[16]

The second deserves recording from other points of view than that of the nerve injury, and was of dramatic interest throughout.

Case 62.—L.-Cpl. C., age 28. Bomb wounds of lower third of left arm and left thigh, July 28, 1916.

Notes from France.—Foreign body removed from thigh two days after date of wound. Small suppurating wound of left arm.

Aug. 6: Admitted. Wound of arm healed. Small varicose aneurysm with thrill, murmur, and expansile pulsation of brachial artery. No nerve involvement. Suppurating wound of inner side of left thigh. Intense thrill felt over femoral vessels, and loud machinery murmur heard with stethoscope.

Aug. 9: At 5 p.m. severe secondary hæmorrhage from wound on inner side of left thigh.

Operation.—Ligature of profunda femoris. Thrill and hæmorrhage ceased. Wound opened up on inner side of thigh. Large suppurating cavity filled with blood-clot evacuated. Free venous oozing checked by gauze plugging.

Aug. 10: Temperature 105°. Pulse 140.

Aug. 11–15: Remitting temperature 102°–104°. Pulse 120–140. Patient critically ill.

Aug. 16: Pathologist reported pure growth of streptococci from blood. Wound over femoral vessels suppurating. Stitches removed. Respirations rapid. Patient spitting blood-stained sputum. Vaccine treatment begun, 1 million.

Aug. 19: Patient very alert. Incontinence of fæces. Temperature 103°. Pulse 130. Vaccine, 2 million.

Aug. 22: Patient no better. Passes 4 ounces of blood per rectum. Vaccine, 4 million.

Aug. 23: Femoral artery visibly pulsating at bottom of wound. While dressing, secondary hæmorrhage from common femoral. Ligatured in bed above hole in vessel. Vaccine, 8 million.

Aug. 27: Patient still very ill, and delirious. Leg and foot warm.

Aug. 28: The ligature tied on Aug. 23 ulcerated through vessel wall. Hæmorrhage controlled by patient. Another ligature tied round common femoral just below Poupart. Later, bleeding began again. No more vessel available for ligature. Patient apparently moribund. Firm pad and bandage.

Sept. 1: Patient rallied. No more hæmorrhage. Vaccine, 16 million.

Sept. 6: Patient worse. Temperature 104°. Muttering delirium. Respirations 40.

Sept. 7: Rib resected under local anæsthetic in patient's bed—large empyema evacuated.

Sept. 9: Sensitized vaccine, 30 million.

Sept. 10: Sensitized vaccine, 60 million.

Sept. 21: Temperature normal for first time since admission. Mental condition better.

Oct. 20: Thigh wounds rapidly healing. Empyema closing. Patient much better. Varicose aneurysm of brachial not increased. Sent to auxiliary hospital.

Nov. 2: Returned for immediate operation on arm. Patient in great pain, with complete paralysis of median and ulnar. Huge pulsating swelling of left arm, extending from axillary border to elbow, and very tense. Scar of wound stretched and thin and on point of giving way.

Operation.—Third part of axillary secured. Very large dissecting aneurysm evacuated. Ulnar and median nerves freed.

February, 1917: Still some numbness in median area and weakness in opponens pollicis. Otherwise cured.

Summary.—Paralysis and pain caused by pressure of rapidly increasing varicose aneurysm of brachial, cured by operation.

The remaining three are cases of injury to the brachial plexus associated with the presence of an aneurysm.

Benisty writes: "Lesions of the brachial plexus have a general tendency to recover," which is explained by the fact that the functional disability following injuries of the brachial plexus is at first greater than would be expected from the actual lesions. This is noticeable in the following cases.

Case 63.—Pte. J., age 21. Bullet wound of right chest, May, 1917.

June: Entrance wound 2·5 cm. below right clavicle, over line of axillary artery. Exit near centre of vertebral border of scapula. Both healed. *Main en griffe.* Finger-tips blue. Great pain and tenderness of fingers. Weakness and wasting of whole arm below shoulder. No paralysis. Thrill palpable over wide area round entrance wound. Machinery murmur, conducted into the neck and as low as bend of elbow. No heart murmur. Thrill and murmur suppressed by digital pressure of subclavian. Radial pulse very weak on right side.

July: No improvement.

Operation.—Vertical incision. Subclavian exposed, and controlled with loop of ligature. Division of clavicle. Artery, vein, and cords of brachial plexus dissected from scar and identified. Aneurysmal varix found opposite point of origin of thoracic axis (*Fig.* 391). Vein hugely dilated below point of communication. Communication between vessels more clearly defined, and ligatured. Thrill immediately ceased and radial pulse became perceptibly stronger. Clavicle wired. Wound closed.

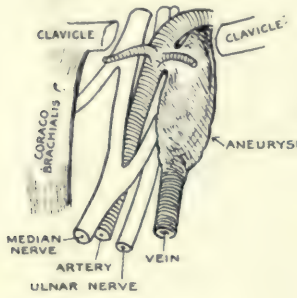


FIG. 391.—*Case* 63. Aneurysmal varix of first portion of axillary vessels.

October: All movements of arm good. Nutrition of muscles improved. No pain in hand. Soft systolic bruit heard over site of ligature. No thrill and no machinery murmur. Transferred to military convalescent hospital.

Summary.—Aneurysmal varix of first part of axillary, complicating compression of brachial plexus by scar tissue. Cured by operation.

Case 64.—Pte. R., age 21. Bullet wound of right shoulder, July, 1916. Wrist-drop. Loss of sensation in little and ring fingers.

September: Paralysis and R.D. in all musculospiral muscles, including triceps. Loss of sensation in ulnar area. Paralysis with R.D. in flexor carpi ulnaris, ulnar half of flexor profundus, and interossei. Wasting and weakness in median muscles, without paralysis. Much pain and tenderness in median sensory area. Musculocutaneous not affected.

October: Unchanged.

Operation.—An incision beginning near inner end of clavicle, and 1 cm. below, was carried outwards as far as the coracoid process. Turning down along the groove between the deltoid and pectoralis major muscles, it ended in the arm 2·5 cm. below the anterior axillary fold. Pectoralis major and minor divided near their insertions, and cutaneo-muscular flap turned inwards and downwards with its vascular and nervous supply intact. Small circumscribed traumatic aneurysm of second part of axillary (*Fig.* 392). Vessel tied above and below and aneurysm removed. Nerves freed from scar. Small lateral neuroma of median.

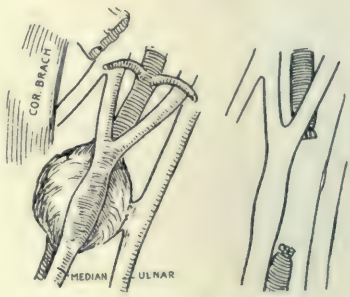


FIG. 392.—*Case* 64. Circumscribed traumatic aneurysm of axillary artery, with injury to brachial plexus. Before and after removal of aneurysm and neurolysis.

March, 1917: Triceps, extensors of wrist, and fingers recovered. Ulnar condition unchanged. Less tenderness in median area.

June: Recovery beginning in ulnar. Voluntary power in flexor carpi ulnaris. Interossei and small muscles still paralyzed.

Summary.—Circumscribed traumatic aneurysm of axillary, with injury to brachial plexus. Considerable improvement 8 months after operation. Slow recovery of ulnar.

Case 65.—Pte. S., age 19. Bullet wound of right shoulder in Mesopotamia, April, 1916. Gradually increasing wasting and weakness of right arm.

July: Whole arm below shoulder wasted. Weak voluntary power in biceps, brachialis anticus, coracobrachialis, deltoid, triceps, and extensors of wrist. Paralysis of extensors of fingers, with absent faradic response but brisk galvanic. Complete paralysis with R.D. of all median and ulnar muscles, with corresponding complete anæsthesia. Large hard mass filling up axilla. No pulsation felt.

Operation.—Exposure as in last case. Very large circumscribed traumatic aneurysm of second part of axillary, extending far down between the latissimus dorsi muscle and chest wall. Artery tied above and below. Sac opened and contents evacuated. Median and ulnar nerves spread out and thinned on anterior surface of sac. Nerves freed.

November: Voluntary power in extensors of finger and thumb. Recovery of protopathic sensation in median sensory area. Voluntary power in flexor carpi radialis. Ulnar condition unchanged.

March, 1917: Continued improvement in median. Voluntary power in flexor sublimis and pronator radii teres. No recovery of voluntary power or sensation in ulna. Tinel's sign half-way down forearm over ulnar.

August: Faradic response in all median and musculospiral muscles. Ulnar muscles still paralyzed, with R.D.

October: Recovery of protopathic sensation in ulnar area. Voluntary power in flexor carpi

ulnaris and flexor profundus. Great improvement in nutrition of hand. Discharged to Command Depôt.

Summary.—Large traumatic aneurysm of axillary, causing paralysis in musculospiral, median, and ulnar. Considerable improvement 15 months after operation.

4. ALTERNATIVE OPERATIONS.

Substitution of the action of the pronator radii teres, flexor carpi ulnaris, and flexor carpi radialis for that of the normal extensors, to render practicable extension of the wrist, fingers, and thumb in cases of irreparable injury to the musculospiral, has been carried out in 4 cases.

The writer cannot agree with Souttar that such operations will be only rarely required. The functional results in this operation are so excellent that it should be regarded as the operation of choice whenever the musculospiral is incapable of repair without the sacrifice of bone or interference with a neighbouring nerve.

A point of great importance in obtaining a good and rapid result is the preliminary education of the muscles which are to be used for the substitution.

The following case is the counterpart of the remainder.



FIG. 395.—*Case* 66. Function of hand after alternative operation for complete musculospiral division.

Case 66.—Pte. P., age 36. Shrapnel wound of left arm, with compound fracture of humerus, August, 1917.

Notes from France.—Posterior cord of brachial plexus severed, 5 cm. destroyed.

October: Wound of axilla healed, leaving very large dense scar. Tinel's sign over scar along radial sensory area. Complete paralysis with R.D. of musculospiral muscles below elbow.

January to April, 1918: Muscle education. Patient taught independent control of flexor carpi radialis, pronator radii teres, and flexor carpi ulnaris.
April: No recovery in musculospiral. Tinel's sign has not spread.
Operation.—Alternative operation described by Sir Robert Jones.
June: Excellent result (*Fig.* 393).

A case of open division of the tendons of the external rotators of the thigh, for a tonic spasm of these muscles following an irritative lesion of the obturator nerve, is, perhaps, on account of its rarity, worthy of record.

Case 67.—Pte. S., age 20. Shell wound of left groin, December, 1917.
January, 1918: Complains of pain in region of left hip. Walks badly, with leg everted (*Fig.* 394 *a*). *X* ray shows foreign body in obturator foramen 15 cm. from surface.



a b

FIG. 394.—*Case* 67. Injury to obturator nerve, causing spasm of external rotators of thigh. *a*. Before; *b*. After division of tendons.

March: No improvement.
Operation.—Foreign body removed. Obturator nerve freed from scar tissue.
April: No improvement in spasm of external rotators of thigh.
May: Correction of position in plaster-of-Paris.
June: No improvement.
Operation.—Through open incision, tendons of obturator internus and externus divided near their insertions.
July: Walking well. Condition cured (*Fig.* 394 *b*).

5. UNOPERATED CASES.

These number 55. They are divisible into two groups: (*a*) Complete physiological division, 29 cases; (*b*) Incomplete physiological division, 26 cases.

a. COMPLETE PHYSIOLOGICAL DIVISION.—*Table VIII* shows the results in the 29 cases in this group.

Table VIII.—Unoperated Cases of Complete Physiological Division.

Recoveries (April, 1918)	Considerable Improvement	Improvement	No Result
8	7	2	12

Of the 12 cases labelled 'No result,' 2 were cases of musculospiral injury, and afterwards had an alternative operation performed; 3 have since been operated upon—two sutures and one neurolysis capsulectomy; 3 await operation; 2 were transferred to other hospitals; and 2 refused operation.

Of the 17 cases which recovered or improved, 6 were cases of nerve concussion, and cleared up in less than six weeks from the date of injury; the fate of the remaining 11 is shown in *Table IX*.

Table IX.—Details of Improved Cases.

	Recovered	Considerable Improvement	Improvement
Number of cases	5	4	2
Average time from date of wound	13 months	11 months	8 months
Longest time ,, ,,	18 ,,	13 ,,	10 ,,
Shortest time ,, ,,	10 ,,	8 ,,	6 ,,

These cases are not recorded in detail, but the general results given in *Table IX* are of more than ordinary interest. At their beginning the cases showed complete paralysis with R.D. in the affected muscles, and complete sensory loss, yet they recovered spontaneously along the lines which would be expected to follow a primary suture. The record of one case will be a sufficient commentary on the remainder.

Case 68.—Pte. L., age 19. Through-and-through bullet wound across right popliteal space, March, 1917. Foot-drop.

April: Complete external popliteal paralysis with R.D., and complete sensory loss.

September: No change.

October: Protopathic sensation recovering. Still some loss of epicritic. Formication on percussion over head of fibula. Still paralysis and R.D. in muscles.

November: Voluntary flicker of peronei visible. Epicritic loss diminishing.

January, 1918: Voluntary power in tibialis anticus.

August: Voluntary power and faradic response in all muscles supplied by external popliteal. Pin-prick and brush everywhere felt.

Summary.—Spontaneous recovery after 16 months.

The question may well be asked: What condition of the nerve would have been found had exploration been performed at the end of five months, when to all appearance the patient suffered from a complete division of his external popliteal? While proof is impossible, there is strong presumptive evidence that these cases are those with spindle-shaped neuromata. Compare *Table IX* with *Table VI*, and note the extraordinary parallel between the average time from date of wound to date of improvement and recovery in those cases known to be neuromata and in those which recover spontaneously.

At present, unless many months are allowed to elapse, and unless frequent examinations are made, there are no means of distinguishing between a nerve which has undergone complete anatomical section, and one injured, which is about to undergo, but has not yet undergone, spontaneous repair.

Are we then to wait six to eight months before exploring? Quite definitely, No! Any case with evidence of complete physiological division should be explored as soon as the condition of the wounds admits—if for no other reason than that a complete section

may be found, and so allow of operative repair being undertaken at the earliest date possible. But the writer would enter an earnest plea against exsection of spindle-shaped neuromata, whether hard or soft, whether conducting the faradic current or not, at any period earlier than ten months after the injury.

b. Incomplete Physiological Division.—The fate of these 26 cases is shown in *Table X.*

Table X.—Unoperated Cases of Incomplete Physiological Division.

Recovery	Considerable Improvement	Improvement	No Result
16	7	2	1

SOME GENERAL REFLECTIONS.

It has been quite impossible to study this series of cases without reflecting on some of the dark and unsolved problems of nerve regeneration. Let it be said at once that Cone's researches have been a fruitful source of inspiration, and have explained many points which were obscure. In these reflections, the spindle-shaped neuroma has loomed large.

The writer has not seen any case of complete physiological division later than twelve months after injury in which the condition was not a complete anatomical section. On the other hand, many cases with palpable spindles on their nerves have been seen with full and complete recovery. A series of cases in which this condition was present, the majority of which recovered, all of which improved, has been recorded in this paper. A further series of spontaneous recoveries in which there is presumptive evidence that the same condition exists has been noted.

Cone has made a series of remarkable experiments on the growth of nerve tissue taken from war-injured nerves and transplanted into guinea-pigs. From these he concludes that war-injured nerves are ready to unite at both ends of the injury before the end of eight months. These findings receive striking clinical confirmation in the writer's cases by a comparison of the average time from wound incidence to date of improvement noted in *Tables VI* and *IX*. The single case in the series which most bears on this question is *Case* 7. Here definite evidence is available that spindle-shaped neuromata had formed at both ends of a nerve transplant where it joined the injured nerve, and that both transplant and injured nerve had shared in their formation. At the end of ten months axis cylinders had grown through both spindles as well as the transplant.

Have these facts any bearing on the technique of secondary suture? Delagenière, writing of suture, says, "A neuroma is found on the central end, a pseudo-neuroma on the peripheral end. Both are obstacles to regeneration and must be resected and the freed axis cylinders of both ends put in contact." Souttar, after dividing the nerve as near to the point of injury as is compatible with the presence of healthy fibres in the divided end, examines that end, and if the nerve bundles do not appear sufficiently normal, a further slice is removed. Kennedy[17] says, "In all cases it is most essential to see the normal appearance of the fasciculi in the nerve section, and slice after slice must if necessary be cut from the nerve end until this is attained, not only in the central but also in the peripheral end." Further on, he says, "It is not safe to reunite a nerve trunk by means of the bulbs: some result might be obtained in this way, but it is apt to be imperfect; the connective-tissue element in the bulb may contract and interfere with the conductivity. It is therefore right to remove the bulbs entirely." The writer does not know whether these last remarks on the reunion of nerve trunks by the bulbs are the result of clinical observation of cases so treated, or whether they are merely the *a priori* reasoning from histological researches. But the point in question is one of great and

immediate importance. All the suture cases in this series have been dealt with by the method advocated by these writers, yet few, if any, have equalled either in rapidity or completeness the recoveries which occur after neurolysis capsulectomy or after spontaneous cure. May not the bulbs be the two separated halves of a spindle-shaped neuroma? Moreover, in all recovering cases in which the suture line of a repaired nerve was available for palpation, a small spindle-shaped swelling has been felt. Kennedy has also apparently noticed this, for in advocating dislocation of a sutured ulnar nerve to the front of the epicondyle, he gives as his reason, "that the enlargement which forms at the seat of suture compresses itself against the rigid boundaries of the sulcus and thus prevents conductivity." In other words, after a resection suture, the nerve re-forms a spindle-shaped neuroma in the course of its repair. The matter is one which can be settled only by an appeal to treated cases, and, with this end in view, the writer has now under observation three cases in which, after performing a capsulectomy of the bulbs, the nerve trunk has been reunited by their suture. It is hoped to report the result of these cases in a later communication.

CONCLUSIONS.

1. In the majority of cases, delayed end-to-end union of a divided nerve is successful, and this method of repair is that of choice.

2. There is something to be said for reunion of nerve trunks by suture of bulbs. An apeal to the results of cases so treated is the only way of settling this important matter. This is being done.

3. The anatomical continuity of a nerve deserves the greatest respect.

4. Exploration of a physiologically completely divided nerve should be done as soon as the condition of the wound permits.

5. Neurolysis combined with a capsulectomy of spindle-shaped neuromata has been followed by recovery in most, and improvement in all, cases in which this has been done.

6. Exsection of a spindle-shaped neuroma is not justified unless failure has resulted from a neurolysis capsulectomy.

7. Nerve transplantations, and double lateral implantations of the ulnar into the median in the forearm, have been followed with some measure of success, including some recovery of voluntary power in the affected muscles; but recovery is slow and uncertain.

8. Nerve growth takes place from both ends of a divided nerve, and from both ends of a nerve transplant, but axis cylinders grow down only from the central end.

9. An autogenous nerve transplant, of smaller size than the nerve into which it is planted, is capable of hypertrophy.

10. Axis cylinders, judged by Tinel's sign, grow at the average rate of 2 mm. per diem.

11. Perineural scar tissue constricting young axis cylinders is the most important factor in hindering recovery.

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FRACTURE OF THE FEMUR: A METHOD OF HOLDING THE FRAGMENTS IN DIFFICULT CASES.*

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Some fractures of the femur resist all attempts to maintain reduction by ordinary means. Lane's plates, screws, wiring, medullary pegs, and bone grafting, all have the disadvantage of introducing a foreign body into a septic or potentially septic wound, and this renders them inapplicable to most compound fractures. Hey Groves' apparatus has several disadvantages: its application involves a complicated operation in the depths of the limb; it may involve opening the marrow cavity; and it does not give absolute immobility to the fragments. The apparatus here described was designed to meet the requirements of these difficult cases, and may be applied in any case in which the great trochanter and condyles are intact, regardless of the site of fracture or degree of comminution. It is an attempt to procure absolute fixation by external means. The one possibility of failure is that of sepsis developing in the cancellous tissue of the great trochanter, which possibility should be negligible with careful asepsis.

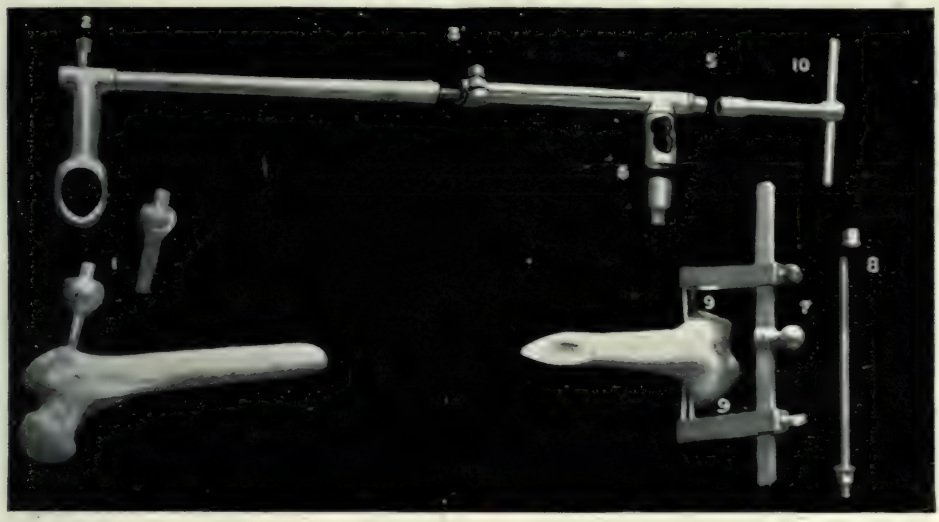
The apparatus is made of steel throughout, and the principle which makes it possible is that of a locking universal joint. A peg (1, *Figs.* 395, 396), rectangular in cross-section is designed to be driven into the great trochanter until it meets the firm resistance of the calcar femorale (*Figs.* 397, 398). No preliminary drilling should be done, thus ensuring the least possible destruction of bone, and preventing the possibility of contamination by several different instruments. The two narrow surfaces of the peg taper slightly towards the chisel-shaped point, the cutting edge of which is made by bevelling the two broad surfaces. This shape is an adaptation of the principle of the square nail which joiners use to avoid splitting. In driving a square nail, the parallel sides are in the plane of the grain of the wood—the taper crosses the grain—and in this way the peg should be driven into the bone. This will not split even a dry bone. The chisel point prevents the possibility of driving bits of cortex ahead of the peg into the cancellous bone, while the taper ensures its being firmly seated. The butt end which protrudes beyond the skin is a ball.

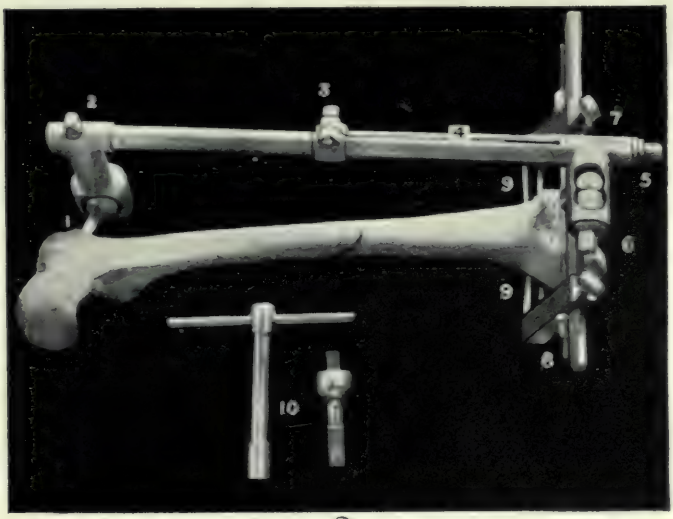
The condyles are grasped by double-pointed calipers (9, *Figs.* 395, 396), made firm by a transverse screw (8), which approximates the points when tightened. There is abundant room in a longitudinal direction on the condyles for these double-pointed calipers, which have the advantage of absolute control over the lower fragment, as against the partial control of the single-pointed instrument. They can be used without the rest of the apparatus for extension and elevation of the lower fragment in supracondylar fractures (*Fig.* 395). A ball (7) is fixed to the arch of the caliper body.

The two balls, one fixed to the trochanter (1) and one to the condyles (7), are connected by a telescoping steel bar, on either end of which a socket receives the respective balls. Each of these sockets is fitted with a locking screw (2, 6), which, when set, converts the ball-and-socket joint into a fixed angle. The length between the two ends of the telescoping rod is increased or diminished by a screw which runs through

* Messrs. Allen & Hanburys, 48, Wigmore Street, London, have a model of this apparatus, and can supply it to order. Also the American Red Cross (Splint Department), Paris, have a model, which may be obtained by applying to them at 4, Place de la Concorde.

it (4). The outer tube is slotted and fitted with a locking collar (3). Thus, the bar can be twisted on itself to any degree, and locked Every possible relation can then be produced between the great trochanter and the condyles.





FIGS. 395 and 396.—Illustrating the parts of the apparatus. (The apparatus has been simplified since this case was treated.) (1) Peg and its socket. (2) Lock-nut for trochanteric socket. It is in an easily accessible position. (3) Locking collar and length screw (4). (5) Nut for length screw. Note easily accessible position. (6) Nut for condylar socket. (7) Ball attached to condylar calipers. (8) Transverse condylar screw for gripping condyles. This is not needed on the later model. (9) Double caliper points. (10) Wrench which fits all nuts.

Case Report.—L.-Cpl. C., wounded April 5, 1918, by bullet driving contents of pocket into thigh.

OPERATION on April 6, at C.C.S.; wound excised, bullet removed. April 8. Admitted to general hospital on Thomas splint, general condition poor. Abduction 30°, 15 lb. weight and pulley extension. April 16. *X* ray shows over-abduction of lower fragment. April 22. Abduction 15°; 20 lb. extension; splint changed from large to small ring Thomas. On April 25, *x* ray shows

upper fragment persists in adduction (*Fig.* 399). Adduction 10°. May 5. Genuflexion 20°; adduction 20°; 20 lb. extension. May 10, despite all attempts to hold the fracture in position, malposition recurs. Skin over great trochanter dressed with alcohol for forty-eight hours.

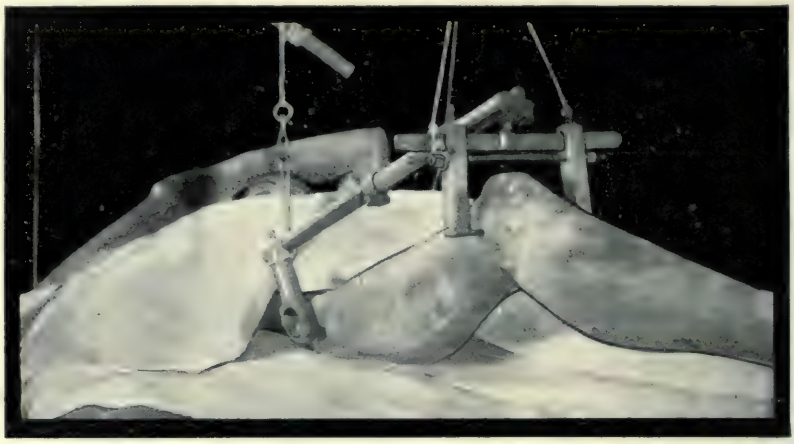


FIG. 397.—Apparatus with dressings removed. The entire thigh is free for inspection and dressing. Note the dependent posterior drainage incision (made May 18); the normal outline of thigh; the absence of inflammation about trochanter and condyles; and also the preservation of the musculature of calf, due to active exercise of ankle and knee.

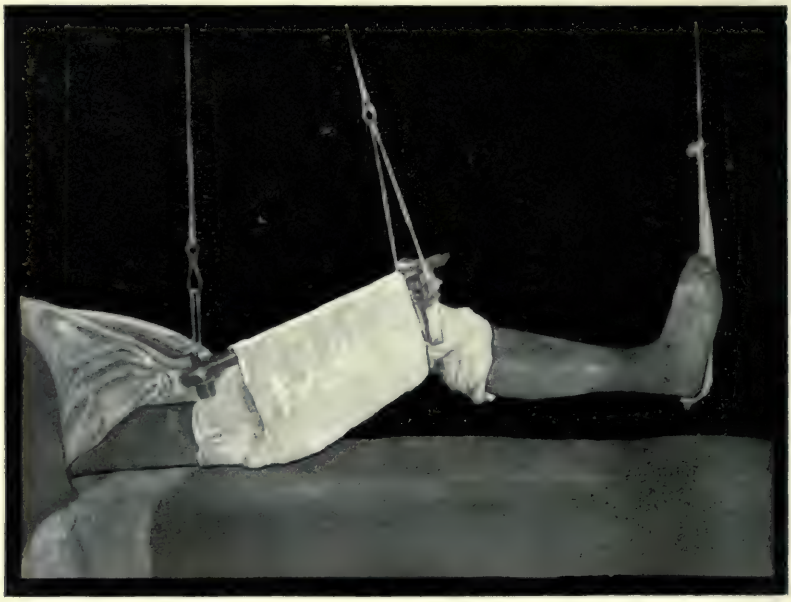


FIG. 398.—Apparatus with dressings in place and rope suspension of thigh and foot. The ropes are carried over pulleys with counterweights attached, thus permitting each rope to be moved independently. The dressings over the peg and the caliper points were changed only three times in 24 days.

SECOND OPERATION.—May 12. Ether anæsthesia. Thomas splint removed. Incision one inch long made longitudinally over great trochanter, carried to the bone, and packed with dry gauze until oozing ceased. It was then dried with alcohol, and a small amount of B.I.P.P. rubbed into the incised skin and subcutaneous tissues. The steel peg was now driven directly into the bone by blows from a steel hammer until the point seemed firmly embedded in the

calcar femorale. A dry dressing was applied, leaving the ball of the peg protruding. Incisions one inch long were made over the condyles in a longitudinal direction. They were packed with gauze until all oozing ceased, dried with alcohol, and rubbed with B.I.P.P. The double-pointed calipers were affixed to the cortex of the condyles, and dry dressings applied. This technique provides for the driving of the peg and the application of the calipers to be made through an antiseptic—B.I.P.P.—a small amount of which the peg carries with it into the medulla of the trochanter, where it acts as a barrier to possible infection.

The connecting telescopic bar was now put in place. The ball-and-socket joints were not yet set. The fracture was then reduced while an assistant set the locking-screws. The length of the femur can be controlled either at once (which I did), or subsequently in stages, by simply screwing the telescopic arrangement. The patient was put in bed, and counter-weights were arranged to support the weight of the leg (*Fig.* 398).

A discharge from the anterior wound, which had been about a drachm of thick pus daily,



FIG. 399.—Radiogram taken April 25 on Thomas splint shows upper fragment in adduction. There is shortening of 1¼ in. This is practically the same as the radiograms taken on April 16 and early in May.

ceased from May 12, only appearing on May 17, and therefore indicating pocketing posteriorly due to the absence of the supporting bands.

THIRD OPERATION.—May 18. Chloroform. Posterior drainage established. Correction of position of bones with fingers in the wounds while an assistant tightened up the screws.

June 4. Position good (*Fig.* 400): 1½ cm. over-length, no fever, pulse normal. Active motion knee 35°. Ankle normal. Hip slightly limited. Patient has been able to sleep on his side and to move about actively in bed. Up in chair to-day with apparatus in position. June 5. Plaster cast applied. Splint removed. Considerable force was required to loosen peg in great trochanter. No evidence of rarefaction about peg. Cultures taken from peg in bouillon and on agar were sterile. June 9. Discharged to England, soft union, good position, general condition good. Wounds over condyles and great trochanter sealed with dried serum.



FIG. 400.—Radiogram taken June 2 shows final antero-posterior position.

This apparatus makes the patient *comfortable*, produces and maintains accurate reduction of his fracture, eliminates support bandages which obstruct dressing and free drainage, and leaves the hip, knee, and ankle-joints free for early passive motion. The bed can be left in its flat position rather than elevated at the foot, so that there is no tracking

upwards of pus. It allows active motion so soon as infection clears up. The patient reported above was able to extend his knee *actively* two weeks after the appliance was put on. These advantages are the result of the absolutely rigid fixation which is obtained. There is no transfixion of bone ; there are no parts buried deeply in muscular substance ; the points of application are at the limits of the bone and are subcutaneous ; the peg in the trochanter, being rectangular in section, gives a purchase for flexion or extension of the upper fragment ; there is no danger of involving the knee-joint by piercing the intercondylar notch ; all parts can be locked ; and finally, it produces rigid immobility, and it can be applied to the fracture in its unreduced position, and reduction accomplished as well as maintained by the instrument. Its application is simple and easy.

It is applicable to any case where plating and wiring would be indicated, and does not have the disadvantage of introducing a foreign body into the wound or its neighbourhood.

I hesitate to publish this report based on only one case, but since the war promises to be over soon, and since the apparatus was so satisfactory in its performance, it seems advisable to bring it to the attention of those who may have difficult cases of fractures of the femur. It has been applied to more cases recently, and promises to give equally satisfactory results, which I may report at a later date.

I desire to acknowledge my indebtedness to the work done by Lieutenant-Colonel Beasley, M.C.N.A., U.S.A., in demonstrating the utility of the caliper which has made this instrument possible. I am indebted to Major E. Granville Crabtree, R.A.M.C., Harvard Unit, and to Mr. G. A. Mower, of the Sturtevant Engineering Company, for valuable mechanical suggestions. Through the kindness of Lieutenant-Colonel Hugh Cabot, R.A.M.C., Harvard Unit, and Lieutenant-Colonel Spencer-Mort, R.A.M.C., I am permitted to publish this paper.

THE RECOGNITION AND SIGNIFICANCE OF FRACTURES OF THE PATELLAR BORDER.

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The object of publishing these observations is to bring to notice the occasional presence of fissures on the outer border of the patella, the importance of which, it is thought, has not been hitherto very generally recognized.

From notes both clinical and radiological, these fissures are found to be caused by some slight *indirect* injury or strain, such as a twist of the knee from overstepping the curb or from vigorous physical exercise. The injury may be so slight that it is difficult to obtain any definite history of it, and at the time of occurrence the patient does not generally realize that anything very unusual has happened. In this respect the condition somewhat resembles the recently described marching fracture of the metatarsals.

The notes of the following case are given as fairly typical:—



Fig. 401.



Fig. 402.

J. P., age 23, was admitted to hospital for an operation for inguinal hernia. He also mentioned that there was a feeling of discomfort and weakness at both knees. Previous to the war he had been a clerk in the City, and had not felt anything wrong with his knees. Pain was first noticed while he was doing physical exercises, fourteen months previously; later, a feeling of weakness at both knees developed after walking for some distance, as if they were giving way. He was very definite that there had been no trauma to either knee. Patient walked in the usual way, and could flex and extend freely both knee-joints, though a certain amount of discomfort was caused in doing the latter. A longitudinal linear depression could be felt toward the outer border of each patella. On moving the bone on either side of it, there was no crepitus, but some tenderness was caused.

Radiographic Examination.—*Right patella*: Anterior view shows a longitudinal fissure near the outer border, and the separated portion fissured into smaller fragments (*Fig.* 404).

Stereoscopic external lateral view shows the detached fragment to be made up of three pieces. *Left patella*: Anterior view shows a longitudinal fissure in same position as opposite side, the separated fragment being of oval shape. Stereoscopic external lateral view confirms the anterior view. The other bones of both knee-joints are quite normal.

Treatment by electric baths, massage, and gentle exercises was tried, but without any improvement in the condition.

Varying degrees of fissure may be observed, from a slight crack with no displacement, to the greater part of the whole border of the patella detached, with, later on, callus thrown out to bridge the gap. The latter condition does not come under the category of fissure fracture, but is included here as being a transition between this and the classical fracture of the patella by muscular action. It is with the former, however, that this paper is intended to deal.

In a series of eight cases of fissure fracture observed, it is noteworthy that in no case was the patient sent to the *x*-ray department for the determination of fracture of the



FIG. 403.



FIG. 404.

patella, but for some such condition as 'synovitis,' 'arthritis,' 'something unusual about bones of knee-joint,' etc.; while in every case he was able to walk up for examination. This is mentioned to show how frequently the question of fracture in these cases is quite unsuspected by the clinician.

Radiological examination shows that the fissures are situated at the outer border or at the external superior angle of the bone. This position would correspond to the line of tension of an overstretched articular capsule, as in lateral bowing of the limbs, or to where the pull of the vastus externus muscle is experienced. A selection from a series of cases showing changes varying from a fine fissure without displacement to a much more extensive condition approaching in character the well-known indirect fracture by muscular action is given in *Figs.* 401–405, and would suggest that the former injuries are either a minor degree of the latter, with the line of force acting in a slightly different direction, or that they are due to an overpull of the ligaments, as in the so-called sprain-fracture.

Radiography.—The technique employed is to take an anterior view of the joint, and stereoscopic external laterals. The latter should always be made, as they will often show the fissures to be multiple, and as many as five distinct fragments have been seen. A posterior view of the joint is of little or no value, on account of the distortion of the patella. Screening alone for the determination of this condition is, of course, quite useless. There seems to be only one condition that might be mistaken for the one described, and that is when the shadow of a sesamoid bone in the outer head of the gastrocnemius muscle just overlaps the edge of the patellar shadow in the anterior view. The lateral plates will help to settle this point.

Treatment.—If the condition be recognized at the time of occurrence, immobilization of the affected limb or limbs with the leg extended for one or two days, but with passive movements started as soon as any hæmorrhage is believed to have ceased, would allow the fragments to join up to the parent bone without any separation. Cases so treated, and with no *x*-ray examination revealing the fracture at the time of occurrence, would leave no trace of the condition for diagnosis at a later date.



FIG. 405.

If the condition is not recognized at the time, and the patient is allowed to go about, the small fragment or fragments will be constantly moved against each other and the main bone, and a sort of fibrous union will take place, which is liable to be upset by any extra strain put on the joint: indeed, it would appear that the condition is quite as often brought to light by this secondary state as by the primary one. The feeling of weakness in the knee is also liable to increase under extra strain, and be accompanied by effusion into the joint, giving rise to recurrent synovitis.

The outlook in cases diagnosed at once would appear to be very good; but in cases with only fibrous union there is the likelihood of some permanent weakness at the joint—depending on the degree of fracture—for which it is difficult to do much, apart from avoiding any undue strain.

It is hoped that these observations on fissure fractures of the patella will draw attention to the importance of early and accurate diagnosis and suitable treatment in the case of seemingly trivial injuries and complaints about the knee-joint.

SUMMARY.

The chief points in this condition are:—

1. The difficulty of obtaining a definite history of trauma, though on careful interrogation a story of some slight indirect injury may be elicited.

2. It may be right-sided, or left-sided, or both, according to the exciting cause.

3. The seat of any discomfort or pain is usually on the inner side of the patella, while the fissure fractures observed have been without exception on the outer border.

4. The direction of the line of fracture is either longitudinal, or obliquely downwards and outwards, but not transverse as in the usual muscular fracture.

5. A linear depression may be felt, corresponding to the line of fissure; pressure of the bone on either side of this may elicit separate movement, and generally tenderness, but not crepitus.

6. Synovitis is frequently present, or has been at some previous date, caused partly by the tearing of the synovial membrane with the fissuring of the posterior surface of the patella, and it is prone to recur.

SHORT NOTES OF RARE OR OBSCURE CASES.

AN UNUSUAL TYPE OF FRACTURE DISLOCATION OF THE UPPER END OF THE HUMERUS.

By Captain TREVOR B. DAVIES, R.A.M.C. (T.C.)

Lance-Cpl. J. T. was admitted into hospital on July 14, 1918, having been thrown twice from his horse within a few minutes, alighting each time on his right shoulder. He was helped on to his horse after the first fall.

X-ray examination showed a subcoracoid dislocation of the head of the humerus, together with a spiral fracture passing downwards and inwards from the outer part of the head, ending on the inner aspect of the shaft of the bone just above its centre (*Fig.* 406).



Fig. 406. Fig. 407.

Under a general anæsthetic the joint dislocation was reduced by a combination of Kocher's method and manipulation of the upper or inner fragment. The fracture was then reduced, and the arm bandaged to the side of the body. No splint was used. The *x* ray taken immediately afterwards showed the fragments to be in good position and the dislocation satisfactorily reduced. Passive movements of the limb were begun a week later, and at the end of a fortnight the patient was encouraged to move his arm.

An *x*-ray plate taken seven weeks after the accident showed union in good position (*Fig.* 407), and the patient left hospital a few days later with practically normal power of movement in the right shoulder.

A CASE OF SEPTIC INFARCT OF THE SPLEEN, CAUSING RUPTURE OF THE SPLEEN, HÆMORRHAGE, AND DEATH.

By ALAN H. TODD, London.

Pte. T., age 40, was wounded by a shell on Dec. 19, 1917, and sustained flesh-wounds of the left arm, shoulder, and thigh, and a compound fracture of the right leg. At No. — C.C.S. it was found that the right anterior and posterior tibial arteries were torn, and that there was gas infection of the tissues of the leg. Supracondylar amputation by the flapless method was performed, and 500 c.c. of blood were transfused. The wound of the left thigh was excised, and a metallic fragment removed; the wound was plugged with gauze soaked in Dakin's solution, and both were dressed with Morison's B.I.P.P. paste. On the following day the transfusion was repeated, 500 c.c. being given. On Dec. 21, at No. — General Hospital, it was recorded that the wounds were 'fairly clean.'

On Dec. 28, the patient was admitted to Lewisham Military Hospital. The amputation wound was exuding much thick green pus, and granulations were exuberant and foul. Two days later a dose of 500 c.c. of A.T.S. was given. On Jan. 3, 1918, the patient had an irritating cough, and some expectoration; he stated that he had 'always' had bronchitis in the winter, and that he had had it prior to his return to England. His temperature showed a moderate irregular pyrexia. He was raised in bed, and a simple expectorant ordered. His general condition was only moderately good. On Jan. 9 (six days later), he complained one night of a sudden stabbing pain over the left lower ribs; he was examined by the orderly officer, who could hear nothing abnormal with the stethoscope, but thought that the trouble was probably pleurisy, and ordered morphine hypodermically. Five hours later the patient collapsed very suddenly, and died before medical aid could be obtained.

At the post-mortem it was found that though the amputation stump was soaked with stinking green pus, the right and left femoral and iliac veins were perfectly healthy; there was not the slightest roughening or injection of the intima, nor any suggestion of past or present clot in them. The pelvis and left hypochondrium were full of blood and recent clot. The spleen was torn right across, and had bled profusely; a great mass of loose clot protruded from it. The spleen pulp, as much of it as was recognizable, was very soft, and there was a thick coating of fibrin on the exterior of the organ—evidence of recent perisplenitis. The capsule of the spleen was firmly adherent to the diaphragm, the muscle of which, in the neighbourhood, was pale and infiltrated. The lower part of the left lung was compressed, and there was slight general bronchitis. No other abnormality was found; a blood culture was negative, and no proof of general septicæmia could be adduced.

The temperature throughout the illness never exceeded 102°, and was of a mild septic type; just before death occurred it dropped suddenly.

Cases of infarction of the spleen are common enough. Those who make a practice of attending regularly in the post-mortem room will be familiar with them, not only in cases of pyæmia or of infective endocarditis, but also in persons dying from some quite independent malady, where they are presumably the relic of some long-forgotten 'pain under the heart.' Sometimes, indeed, the spleen is seen to be covered, as this one was, with a thick layer of fibrin, and to be densely adherent to the diaphragm and abdominal parietes. But it is very rarely indeed that the spleen, unless a malarial one, is found to have ruptured spontaneously, and to have killed its owner by hæmorrhage. It is on account of the extreme rarity of this accident, in contrast with the comparative commonness of splenic infarction, that this case is recorded. It must be emphasized, moreover, that apparently the spleen was inflamed for some hours, possibly for some days, before rupture occurred.

I have to thank Lieutenant-Colonel Toogood for his courtesy in permitting me to publish the case.

BILATERAL OVARIAN DERMOID CYSTS SIMULATING RENAL COLIC.

By C. H. FAGGE, London.

Nurse H., age 27, complained one evening of dull 'stomach-ache,' which she had endeavoured to treat with castor oil, but without success. The history she gave was that she had had scarlet fever in childhood, but no other illness of importance; the recent pain had been at first a diffuse abdominal pain; she had taken a dose of oil, and then, as the first dose made her sick, she had taken another.



Fig. 108.—Radiogram showing two teeth in ovarian dermoid cyst.

The medical man who first saw her regarded the case as one of so-called gastritis, and gave her a little chlorodyne; this alleviated her pain, and she slept fairly well. By the following evening, however, the pain had returned; it originated in the left loin, radiated to the left subcostal region, round the waist, and (a little later) towards the groin. It was of a colicky nature, and accompanied by nausea, though not by actual vomiting. No tumour could be felt in the renal region, or elsewhere, and the urine was reported by the sister of the nurses' sick-room to be normal upon chemical examination.

Renal colic due to calculus was suspected, and a radiogram was taken, which cleared up the diagnosis (*Fig.* 408). Two teeth were to be seen very plainly at the level of the pelvic inlet : the root-canals can be distinctly made out in the original plate. Since the patient had not swallowed any teeth, it was evident that she was suffering from an ovarian dermoid cyst. Moreover, radiograms of the kidneys showed no evidence of calculi, so that the cyst was probably the cause of the symptoms, and not merely incidental.

The patient was transferred to a surgical ward. Whilst awaiting the visit of the surgeon in charge, a sudden change occurred in her condition : she began to vomit violently, and became distended and tympanitic ; in short, she showed not only signs of pressure upon the ureter, but of intestinal obstruction. It should be remarked that prior to this attack of obstruction, she had suddenly passed an unusually large quantity of urine, suggesting that the renal symptoms which had predominated at the early stage of her illness were due to hydronephrosis—closed at first, and finally open.

In view of the sudden change in the patient's condition, laparotomy was performed with the least possible delay : it was found that there were two ovarian cysts, firmly impacted in the pelvic brim. Both were multilocular, and contained hair and pultaceous matter of the usual kind : the teeth were found in the right cyst, whilst the left cyst had evidently pressed upon the pelvic colon and caused the obstructive symptoms. The left ureter showed no external sign of obstruction, though some hours had elapsed since the discharge of urine, so that it is not surprising that no such sign was seen, and the absence of any such indication in no way controverts the diagnosis of hydronephrosis. The pelvic colon showed the usual signs of recent moderate obstruction. Both cysts were excised. No trace of ovarian substance or of supernumerary ovaries could be seen macroscopically. Recovery was uneventful.

The further history of the case is not at present ascertainable, but it seems probable that complete amenorrhœa will soon set in, with all the ordinary train of physical and psychical changes, for the girl's appearance, prior to operation, was such as to suggest that her supply of ovarian internal secretion had long been deficient.

The main interest of the case centres in the unusually complete simulation of renal trouble at the start, and then the sudden transformation into a case of intestinal obstruction : also, in the rapid and certain aid to diagnosis afforded by the *x* rays.

The teeth in the right dermoid were about as long and as thick as adult canines ; the crowns were slightly flattened, and showed several little cingulæ near the top : each tooth had a single root, though the apex of one of them was a little bent to one side. No trace of dental or bony matter was found in either cyst beyond these two teeth, though there were a few partially-calcified areas in the débris.

REVIEWS AND NOTICES OF BOOKS.

The Breast: Its Anomalies, its Diseases, and their Treatment. By JOHN B. DEAVER, M.D., LL.D. and J. MCFARLAND, M.D., assisted by J. LEON HERMAN M.D. Large 8vo. Pp. 724 — vii, with 8 coloured plates and 277 illustrations. London: Wm. Heinemann (Medical Books) Ltd. 40s. net.

THIS is a substantial volume of 700 large pages, indispensable to every serious student of its subject. The authors' names raise expectations which are not disappointed. In compiling the work their search through the literature of the subject has been exhaustive. An outstanding feature of the book is the catholicity, completeness, and fairness of its bibliography. Reference will be found to all important papers in English, French, or German. Brief summaries of many of these are given. A striking fact emerges, namely, that nearly all the important contributions to the surgery of the breast are due to the English-speaking races. Were it not for Anglo-American work the surgery of breast cancer would still be in its infancy. In Germany, and even in France, it still lags behind. Just before the war the leaders of French surgery, save for a few of the younger school, were of opinion that removal of the great pectoral muscle was an unnecessary and crippling procedure. Many of them denied the occurrence of cancerous infection of this muscle from the adjoining breast.

Those who wish to form their own opinions from a study of the evidence will be grateful for the fair-minded way in which opposing views are presented, and for the very numerous detailed case-records from the literature. The more cursory student may, perhaps, feel that amid its wealth of detail the book is lacking in clear and strong outlines. He will be better served by a smaller and more compact account of the diseases of the breast; but even he may well find the book indispensable for purposes of reference on particular points of interest.

The volume opens with a section of 160 pages on the evolution and involution of the breast, its surgical anatomy, and its congenital and acquired anomalies. Over 100 pages are devoted to the mammary anomalies, and 66 illustrations of classical or personal cases are given in this section. The nature of the subject demands its treatment by detailed case records, and the section is a masterpiece of historical research among the curiosities of pathology. For instance, a table of 240 cases of mammary hypertrophy, with detailed references and case summaries, is to be found on pp. 120–138. Upon breast abnormalities the book at once takes a position of unrivalled authority. A chapter on wounds and injuries of the breast follows.

The account of carcinoma, to which most readers will turn, occupies 160 pages. It opens with a confession of our ignorance of the cause and nature of cancer in spite of the labours of a generation. This refreshing note of frankness, so essential to the progress of knowledge and so rarely met with in medical works, is conspicuous throughout the book, and the reader responds to it each time with a renewal of confidence and interest.

The authors believe that cancer invariably "begins as a local disturbance at a minute focus, and spreads." Thus they do not recognize the multicentric or diffuse carcinoma which lights up at the same time over a considerable area of the breast. This event is exceptional, but that it occurs is shown by the fact that such a cancer when first detected may take the anatomical sector-shape of the lobe or group of lobes in which it originated.

The authors rightly pillory the ridiculous multiplication of names for so-called varieties of cancer, by giving a list of over fifty of these names. They prefer to insist on unity in multiplicity rather than upon multiplicity in unity, and again the reader breathes a sigh of relief and gratitude. The authors describe six distinct varieties of carcinoma. Curiously, they give no definite account of columnar-celled or duct cancer, a form which in America appears to be included along with acinous carcinoma– a confusion of two varieties often distinct histologically and in some cases clinically. The authors rightly insist that the expressions scirrhus and encephaloid as applied to cancer are clinical, not pathological, and that different sections of the same tumour may show respectively a fibrotic and a cellular form of growth.

The authors thus sum up their beliefs on the dissemination of cancer:—

> "While a number of steps in the progress of dissemination need further investigation, metastasis may for all practical purposes be attributed either to embolism (blood- or lymph-vascular) or to the process which Handley terms 'permeation.'"

They proceed to show that blood has great power of destroying cancer emboli. A full account of the permeation theory follows, and appears to mark the definite acceptance of this theory by American opinion. It is a great gain that agreement has been reached upon the mode of dissemination of cancer, for the surgery of the disease is thereby for the first time placed upon a rational

basis, and an instrument of criticism is provided to decide or reconcile the conflicting claims of various methods of operation.

The chapter on prognosis is the fullest and most scholarly discussion of a difficult subject with which we are acquainted, and is an admirable example of clinical research. We note one important omission. Among the few almost certain elements in prognosis is the development of evidence of internal metastases, when a period of under a year can be put to the patient's life. The authors admit the impossibility of prognosis for any individual case :—

> "We should confine ourselves in prognosing any given case of carcinoma of the breast to the average result obtained in that class of patients to which we believe, from the results of our physical examination, the one under consideration belongs. It has been demonstrated that 80 per cent of patients in whom the disease is confined to the breast as proved by both macroscopic and microscopic examinations of the tissues adjacent to this organ, are permanently 'cured' of their disease by the radical operation. Therefore, a patient presenting a small movable mass localized to the breast, can be assured that four out of five cases of a similar nature are cured by operation. When the axillary lymph nodes are palpably enlarged as the result of metastases, the chances of operative cure are at once diminished to *one in five.*"

The question of palliative operations is fully discussed. The authors fix a five-year limit after operation as the period after which recurrence, though still possible, is unlikely.

As to the influence of the mode of operation on prognosis :—

> "There can be no question at this time of the comparative values of the Halsted and similar radical methods of breast amputation, and the less radical procedures, in those cases which are considered operable.
>
> "It is difficult, if not impossible, to estimate the influence of the various modifications of the original Halsted technique on the prognosis of mammary carcinoma. Extensive removal of the skin with more extensive removal of the deep fascia, as advised by Handley, undoubtedly has served to decrease both local and regional recurrences. We believe that the prognostic effect of preserving the pectoralis major muscle is an evil one, and find our view substantiated by Vanvert."

The authors rightly emphasize the immense impetus given by Halsted to the surgery of the breast, and they still consider his operation as the standard one, with such modifications as are rendered necessary by subsequent research. An English surgeon might here interpolate a claim for the contemporary operation of Stiles and Watson Cheyne, which, in its insistence on the necessity of undermining the flaps extensively, was definitely superior to the procedure of Halsted.

It is possible without violating pathological requirements to devise various methods of removing a breast cancer, and the authors select for description the methods of Halsted, McFarland, Handley, Kocher, Rodman, Stewart Murphy, Dawbarn, Meyer, Tansini, Warren, and Jackson. The plastic methods, such as that of Tansini, are rightly condemned. Our complaint here is that the various methods are not submitted to rigid pathological criticism, and the reader is practically left to choose between them. For instance, the indifference of Kocher to the precise location of the tumour in the breast is not commented upon. He would apparently perform the same operation whether the growth is situated under the nipple or at the axillary edge.

A welcome chapter is that by Dr. George E. Pfahler upon the non-operative treatment of cancer of the breast. The scope of these methods is rightly limited to cases unsuitable for operative treatment. The encouraging nature of the results attained by x rays and radium is fairly presented. It is pointed out that, in dealing with such large areas as are affected in breast cancer, x rays usually possess the advantage over radium.

In the chapter on Paget's disease, the authors give what is one of the best accounts of the histology of the condition, evidently from careful first-hand observation. As to the nature of the disease, they reserve judgement. The references to the literature of this affection occupy seven pages at the end of the chapter, an illustration of the authors' conscientious work, and of the perennial controversy which centres around the pathogenesis of the disease.

Our chief criticism of the book, and perhaps of the present tendencies of thought among surgeons generally, is the authors' expressed willingness to trust for guidance to the comparative statistical results of different methods of operation rather than to the light of accurate knowledge based upon pathological research. They say, for instance, "There are many phases of the problem of metastasis that cannot be considered in a treatise of this kind, but they are of little practical moment"—a sentence which suggests, however erroneously, that they turn from the complex problems of dissemination with a gesture of intellectual fatigue. The complement of the last-quoted words is found on p. 603, where the authors say : "Whether or not there be a *best* routine operation for mammary carcinoma remains to be shown. The only way to settle the question is to ascertain the comparative end-results in large series of cases after removal of the breast by different methods." To illustrate our point of disagreement, let us take a geographical illustration. If it is required to find the best route between two cities for a railway, the method adopted is not to follow the sinuous sheep-tracks of hoary tradition, or even the broad highways of recent years, which represent the survival and development of the fittest of these tracks. The modern method is to survey the country and ascertain the levels and the local conditions. Only then is it possible to

reduce infinite possibilities of devious error to a single best, or to a choice between a few equally good alternatives. The surgeon must look to the pathologist, and not to statistical comparisons of end-results, riddled with sources of fallacy, for the guidance which the railway engineer gets from the surveyor. If the English surgeon has learnt from America to study and appreciate surgical workmanship and to reform a slipshod technique, his American colleagues may perhaps in their turn remember with advantage that first-hand pathological knowledge is the only safe guide for their skilful hands.

This review is necessarily incomplete, but we have said enough to persuade all serious students of breast surgery that they must possess the book.

Tumours of the Nervus Acusticus and the Syndrome of the Cerebellopontile Angle. By Harvey Cushing, M.D. Harvard. Large 8vo. Pp. 296, with 262 illustrations. 1917. London and Philadelphia: W. B. Saunders Co. 21s. net.

Professor Harvey Cushing's book is both a record of a great surgical advance and a model of how such a record should be made. Since the beginning of this century a miasma of depression has settled upon the field of neurological surgery, originating from an honest and fearless recognition of the fact that the end-results in the mass are bad. Nor is there any ray of hope for the victims of most intracranial tumours from an alternative method of treatment. The patient and splendid work of Cushing during the last fifteen years, as revealed in this book, has dispelled at least some portion of the cloud. It is not only the practical achievement of the reduction of an operative mortality from an average elsewhere and everywhere of 70 per cent to under 14 per cent in his own clinic that compels admiration; but, further, it is the picture presented of vision and courage in the face of overwhelming difficulties and disappointments, recognizing failures with fearless honesty, rectifying them with consummate judgement and skill, and finally achieving the triumph so modestly set forth in these pages.

Beginning with a historical review of the earliest records of these cases—among which the most notable are those of John Bell in 1830 and Jean Cruveilhier in 1835—he traces the progress of knowledge through the differentiation between supra and infra-tentorial tumours; to the further subdivision into extracerebellar and intracerebellar lesions; and finally to the stage of recognition where tumours of the cerebellopontile angle assume a clinical identity. At this stage his own work begins, and from the nebular tumescence of the cerebello-pontile angle there now emerges the precisely formulated conception of 'tumours of the nervus acusticus,' which possess a unique histological structure, are constant in their anatomical relations, produce a sequence of clinical signs and symptoms of unmistakably clear significance, and are amenable to a modified surgical procedure that transcends through its success all previous endeavours in this region.

The terms 'acoustic tumour' or 'acoustic fibro-neuroma' have been deliberately chosen by the author in preference to any of the other twenty-three names already suggested by other writers (p. 195) as most appropriate to the cellular structure of the growths. This structure is composed of two main sorts of tissue—a dense fibrous tissue whose oval nuclei tend to be grouped in a "characteristic palisade arrangement," and "a loose areolar tissue possessing some of the architectural characteristics of a glioma." "The tumours are specific for the acusticus, and should not be confused with other growths arising in the cerebellopontile angle." Such a fixity of structure of tumours within the substance of the nerve, and of their origin from the distal portion of the nerve within the auditory canal, is in accordance with Sternberg's view that they are of embryonal origin—a view that receives additional support from a consideration of the mode of development of the eighth nerve.

Their anatomical relationships need the careful consideration that Cushing has bestowed upon them, so that an intelligent forecast of what symptoms may be expected from their presence can be made, and a right understanding of their significance may be achieved. Of immediate surgical importance is the fact that they are situated beneath the arachnoid, which may distend enormously with fluid over their surface, giving the appearance at operation of a large cyst. Unless this has been sufficiently appreciated, the cyst may be punctured in the belief that it is the lesion sought for, whilst the underlying tumour remains undiscovered.

The symptoms and signs are elaborated by the author with a wealth of detail that provides a mine of information, prevented from overwhelming the reader with its encyclopædic load by the clarity and precision of his writing. His general conclusions alone can find space in a review. He states (p. 176) that the "symptomatic progress of the acoustic tumour occurs more or less in the following stages: (1) The auditory and labyrinthine manifestations; (2) The occipito-frontal pains, with sub-occipital discomforts; (3) The incoordination and instability of cerebellar origin; (4) The evidences of involvement of adjacent cerebral nerves; (5) The indications of an increase in intracranial tension, with a choked disc and its consequences; (6) Dysarthria, dysphagia, and finally cerebellar crises and respiratory difficulties." Further (p. 152): "The chronology of symptoms makes it clear that the clinical diagnosis of an acoustic tumour can be made with reasonable assurance *only when auditory symptoms precede* the evidences of involvement of other structures in the cerebellopontile angle. Hence, when the inaugural symptoms of a growth obviously situated in the angle have another sequence, *with secondary acoustic symptoms*, the diagnosis must remain uncertain until the lesion is exposed." The large series of cases successfully diagnosed

and submitted to operation affords the best proof of the validity of his conclusions. It is clearly of great practical value that the sequence of the symptoms should be so constant, and that the earliest should arise in the special sense organ to which the affected nerve is distributed.

Once more the importance of early diagnosis is urged, and by the pen of the writer whose work has done so much to render it possible. Not the least tragic of his experiences has been the late stage of the disease which many of the patients had reached before being brought to him. Blind and bedridden as many of them were, yet the lease of life was frequently renewed at his hands for a period of from three to seven years. What possibilities are unfolded for successful surgical treatment when cases can be submitted to it in the earlier stages of the disease whose recognition has now become possible through his labours!

The author's methods of operation – which have done so much to standardize the surgery of the cerebellar fossa– are again described in full; his important modification of the enucleation of the contents of the tumour from within its capsule being the essential feature of his new work.

"Middle ear," twice repeated on p. 208, is clearly a misprint for "internal ear," and on p. 181 and p. 190 S. G. Shattock's name is misspelt 'Shattuck.' Such trivial comments as these are a measure of the difficulty of finding any blemish in so splendid a book. Physicians and surgeons alike will find refreshment and reward by reading it.

Surgical Therapeutics and Operative Technique. By E. Doyen. English translation by H. Spencer-Browne, M.B. Cantab., etc.; Elève de l'Institut Pasteur; Physicien et Chef de Clinique de l'Institut Doyen. In 3 vols., large 8vo, with about 3000 illustrations. 1917. London: Baillière, Tindall & Cox. 25s. net each volume.

This English edition is taken from the material from which the second French edition will be compiled, and contains the latest developments in war surgery and surgical treatment in general. Only the first two volumes are ready as yet.

Vol. I contains an Introduction, which deals with the state of surgical practice at the beginning of the twentieth century, with surgical technique, and with the duties and rights of the surgeon. Emphasis is laid on the importance of anatomical knowledge, and on the importance of every surgeon being his own diagnostician, and not merely an operator. The surgeon is encouraged to remember that surgery is not only a science but also an art, and that it is by the excellence of his technique that the artist is revealed. The remainder of Vol. I is divided into two parts, the first dealing with general surgical technique, and the second with the regional surgery of the head.

Part I gives a short account of the arrangements and working of the author's Surgical Institute in Paris, and a much more detailed description of the operating department, including the general management of patients before, at, and after operation, the aseptic and antiseptic methods employed, and anæsthetization.

'Attached services' comprise laboratories for diagnostic research and teaching purposes; and the many-sided character of the Institut Doyen is appreciated on reading the short sketch of these, which include laboratories of bacteriology, serotherapy, chemistry, histology, radioscopy, photography, and cinematography.

There is an interesting chapter on hæmostasis, with plates taken from Serrig's atlas, and a criticism of the methods employed by the older surgeons, which is followed by a description of the author's own instruments and devices for dealing with hæmorrhage. Doyen, besides being a skilful operator, was a mechanical genius, and designed most of his surgical instruments: the somewhat formidable size of many of these is accounted for by his method of operating, which was rapid, and largely a combination of enucleation and crushing. Doyen emphasizes over and over again the importance of operating rapidly: indeed, he says, so far as the patient is concerned, 'time is life'; and for a surgeon of his almost uncanny dexterity such a maxim was undoubtedly a very proper one. This eye-on-the-clock method, however, will hardly find favour with present-day surgeons, who rather take the view that dainty handling and an artistic finish require time and produce the more gratifying results. Doyen clearly recognized the avascular layer which surrounds all organs, in which the enucleating finger or instrument produces the minimum of bleeding, and across which only definite and well-marked vessels run, easy to see and clip; he illustrates this very plainly in the section dealing with the thyroid in Vol. II.

The author's therapeutic innovations are also described, and a brief account is given of his anti-neoplastic vaccine and of mycolysine—a preparation employed by him to prevent and combat acute infections.

This part on general surgical technique concludes with an excellent and full account and criticism of the various methods employed to destroy growths by heat and electro-coagulation. Doyen used a high-frequency current of low tension, the electrode being left in contact with the diseased tissue. He claims priority in the discovery of the deeper penetration by this method, and also of the selective nature of a temperature of 60° C. for pathological tissue. His experience with this form of treatment of carcinoma was a very happy one.

The section on regional surgery, as far as it has been published, occupies the last 140 pages of Vol. I and the whole 680 pages of Vol. II, and deals with the head, neck, thorax, and upper and lower extremities. The general plan adopted in each region is to give a short description of

the clinical characteristics of the disease under discussion, with the indications and contra-indications for operation, the surgical anatomy of the part, a plate depicting the instruments required, with a description of the same, and finally, a description of the operation itself, which is clearly and concisely divided into stages. Each operation is profusely illustrated with most excellent diagrams, which are one of the noticeable features of the book. Many classical, but defunct, operations are not mentioned. The operations are those used by Doyen and his staff, standardized so to speak, and permeated by his technique; where necessary, modifications, such as the experience of the author has led him to adopt to meet complications, are described.

There is a good section on the comparatively recent field of lung and heart surgery, for which Doyen has introduced several excellent instruments. Vascular surgery and blood transfusions are dealt with fully, and in a thoroughly up-to-date manner.

The plan and general treatment of the subject matter, in Vol. II particularly, is refreshingly original, and it is perhaps only what one would expect from a genius who not only constructed most of his instruments, formed a technique peculiarly his own, and introduced many original therapeutic remedies, but who devised many of the operations he performed, and altered most of the others to suit his own characteristic methods.

It was this originality of the author's work, and the great interest shown by the large number of visitors to his Institut in Paris, which led to a general desire for an English edition of his text-book; the French edition has already had a wide success abroad.

Collected Papers of the Mayo Clinic. Vol. IX, 1917. Edited by MRS. MELLISH. Pp. 886, with 331 illustrations. 1918. Philadelphia and London: W. B. Saunders Co. 28s. net.

THAT it should be possible to produce a volume similar in size and in the number of its contributors to those issued in former years, during the year when the United States entered the War, and at a time when the whole nation, and not last in this respect the medical profession, were making most thorough preparations to take their share in its burdens, says much for the enthusiasm and activity of the staff. While there are no papers definitely dealing with diseases or injuries of war, yet this event has clearly set its impress on the volume, in that it has led Dr. C. Mayo to write two papers on "War's Influence on Medicine," and "Medical Service in the United States Army."

The former, his presidential address to the American Medical Association, is a most delightful piece of reading, which shows that the writer is not only the master of wide information, but also has definite and broad views of the demands of national medicine in the States, and of the responsibilities and duties of those engaged in medicine. It will well repay careful reading by all those on this side who are interested in and giving much thought to the remodelling of medical education. While Dr. Mayo expresses in this first article a quite natural and justifiable pride in the accomplishments of his fellow-countrymen in showing that "man's power to control the elements was developed in America," he is under no delusions that their state is a perfect one: in pointing out in his second paper the benefits which the American nation may derive from active participation in the war, he writes: "Our nation is becoming soft, dissipated, and inefficient. . . . We make many laws, but obey few, and having an abhorrence of discipline, we discuss freedom." There is certainly no evidence of this decadence having spread to Rochester, Minn.

In reviewing the medical service in the United States Army, he enters a plea for higher rank for medical officers, and deplores the fact that the Surgeon-General is not a member of the War Council. "This is another of the conditions such as brought about the Mesopotamian failure," which on another page he stigmatizes as the "last atrocious medical failure"; this straight speaking should do good in helping us to realize the defects of our own system and the path along which reform should move.

Dr. L. B. Wilson contributes a complete review of the literature of trench foot, which should be most helpful to those likely to have to treat such cases in future campaigns.

The same author's paper on "Graduate Work in Medicine in the University of Minnesota" shows how the Clinic is tackling this most important question, and tells how in 1915 the Mayo foundation entered into a temporary agreement with the University of Minnesota for graduate work in pathology, medicine, and surgery, which was made permanent in 1917. It appears that the funds for this purpose have been handed over by the Mayo foundation to the control of the University, which indicates a very broad-minded attitude of the former and the wise policy of those responsible—without doubt the Mayo brothers—in thus devoting a large proportion of the earnings of their life-work to the benefit of medicine of the future. We could wish that post-graduate training, now becoming a very live issue in this country, could be directed by equally sage counsellors, for Dr. Wilson's views on "University ideals" are no less admirable than the "general plan" on which it is proposed to put them into execution.

Clinical papers occupy less of this than of former volumes, which fact may be due to the present pre-occupation of many of the staff with military affairs; of those which do appear, perhaps the most valuable is that by Dr. W. J. Mayo in which he deals with forty-two cases of diverticulitis of the colon treated by resection. We are not aware of any paper in which so large a number of operative experiences for this condition have been brought together. The problems and difficulties met with in the course of such operations are handled with the

resource and judgement which those of us who have long sat at his feet have learnt to expect from this writer.

Dr. W. W. Bissell's paper on pulmonary fat embolism thoroughly reviews the pathology of this condition, and is valuable in drawing attention to a post-operative complication which, in the author's opinion, is often confounded with shock from other causes.

Dr. D. C. Balfour discusses the conditions which may call for splenectomy, with a very full bibliography: this paper will carry weight in conjunction with the same writer's former papers on the surgery of the organ, which indicate that his experience has been exceptionally wide.

Of the purely scientific papers, that by Dr. MacCarty on "Cancer's Place in General Biology" is original in conception and most fascinating in suggestion: the cellular reactions are described, and illustrated by beautifully-drawn plates which illuminate the argument. The writer, perhaps wisely, makes no effort to explain why these changes take place.

In our former reviews of the Mayo Papers, we have taken the writers to task because we have held that some articles were scarcely worthy of the institution from which they emanated: those who had not had the unique privilege of visiting the Clinic would, we held, fail to gather from its publications the value of the work which it was really doing for medicine: we felt that its reputation must suffer, and that, from the greatest combined clinical and scientific institution which has been evolved by men still living, nothing but the best could be regarded as representative. To a large extent this criticism no longer holds good, for the first-mentioned papers by Dr. C. Mayo and Dr. Wilson, in mirroring the ideas and character of the institution, can only add to its laurels, and in themselves justify the issue of the Collected Papers.

Gunshot Fractures of the Extremities. By Joseph A. Blake, Lt.-Col. Medical Corps, U.S.A. 8vo. Pp. 136, with 40 illustrations. 1918. Paris: Masson et Cie. 4 fr.

This small book represents the results of practical experience during the present war. The methods of treatment of gunshot fractures represent on the whole that which has been lately in vogue in the British Army and which was described by Ogilvie in the last number of the British Journal of Surgery. The author does not accept Leriche's view of the desirability of the removal of loose fragments from comminuted fractures, but wisely insists on the value of these in regard to regeneration of the bone. He lays great stress upon the importance of maintaining the limbs in a position of physiological rest—that is, with semiflexion of the principal joints. He also urges that active traction by a weight and pulley is much more efficacious than passive traction by tying the limb to a splint. He recommends and illustrates what we consider to be an unnecessarily complicated system of suspension. In cases of severe fractures of the arm he advises a system of traction and suspension, without the use of rigid splints, and we think his arguments for this are quite sound. The sections on vicious union and non-union are too short to be of any practical value, and his reference to the use of inlay grafts gives a misleading impression that this is a satisfactory method of treating ununited gunshot fractures.

The book is a very valuable guide to the matter of which it treats, and it is a matter for regret that it has appeared so late in the war.

Local and Regional Anæsthesia. By Carroll W. Allen, M.D., New Orleans. Second edition. Pp. 674 + 14, with illustrations. 1918. Philadelphia and London: W. B. Saunders Co. 28s.

It is a pity that Dr. Allen's book on local and regional anæsthesia is so bulky. In these busy days, operating surgeons, for whom it would have most value, have little time and no inclination for reading lengthy dissertations. The historical presentation of the subject is interesting. The essence of the technical descriptions is of good quality, but is too highly diluted. The illustrations are excellent and useful, especially those borrowed from the works of Braun and Härtel. The syringe and attachments recommended by Dr. Allen are inferior to those used by most British surgeons who use local anæsthesia extensively. The syringe is too small, and there is no rapidly-locking arrangement which prevents the nozzle being forced off. The admixture of ¼ per cent potassium sulphate with the anæsthetizing solution, which has been found by other surgeons to enhance and prolong the anæsthesia, has apparently not found favour with Dr. Allen. We join with him in recommending the study of the anatomy of the nervous supply of parts which are to be operated on under local anæsthesia. Failure is frequently due to want of this anatomical knowledge. A concise description in English of the technique necessary for success is very desirable.

The Treatment of Infected Wounds. By A. Carrel and G. Dehelly. Second English edition. 81 figures and 6 plates. 1918. London: Baillière, Tindall & Cox. 6s. net.

The only defect in the original edition of this classic work was the omission to provide sufficient information as to the results obtained by the treatment now so well known and so widely practised under the name of the Carrel-Dakin method. In the edition before us this has been remedied, and the reader will also find information as to the results obtained by the method in the treatment of wounds, fractures, and joint injuries that are not of recent origin. What will be the exact scope of the method after the war it is of course impossible to say; but the book is more than welcome, if only as a memorial of a most brilliant and valuable research planned under circumstances of great stress and brought to achievement within a phenomenally short time.

Applied Anatomy: The Construction of the Human Body considered in relation to its Functions, Diseases, and Injuries. By Gwilym G. Davis, M.D., M.R.C.S., Professor of Orthopædic Surgery in the University of Pennsylvania. Fifth edition. Pp. 630, illustrations 631, many in colour. 1918. Philadelphia and London: J. B. Lippincott Co. 30s. net.

This is the fifth edition of Professor Davis's sumptuous book. It contains a wealth of illustrations, many of them in colour, by Mr. Erwin F. Faber. The profusion of illustration is realized when one finds that there are 631 pictures in 630 pages.

The book is obviously the work of a trained teacher. The language is terse, and always clear. The anatomical facts are presented to show their value in relation to the art of surgery. The book is essentially practical. It is sound anatomy, and happily is written in the old terminology, a point which should enhance its value to students. One is amused to see the old error about the angle of Ludovicus (Louis), this cropping up in several places as the 'angle of Ludwig.'

Development is introduced to explain anomalies and deformities. The embryological references are sometimes misleading, or too brief to be sufficiently explanatory. The vexed question of the development of the sternum is too summarily dismissed; and in relation to the subject of imperforate anus, there is an inadequate account of the development of the cloaca, etc. The account of the development of the genito-urinary system is rather superficial.

The subject is treated regionally, and the best sections are those on the neck, thorax, and abdomen. There is an excellent and accurate account of the abdomen, and of hernia, with very good illustrations. It is in relation particularly to the limbs that one is disappointed that a Professor of Orthopædic Surgery should leave so much that is of prime importance unsaid. While there are many excellent paragraphs in the description of the upper limb—notably in the sections dealing with dislocations and fractures in the region of the shoulder—the account of the joints, tendons, and peripheral nerves is weak. In the account of the lower limb, similarly, there is a very sketchy account of the joints and nerves; and the deformities of the foot are treated in a perfunctory manner. One must draw attention particularly to the almost complete silence of the author on the subject of the semilunar cartilages of the knee-joint. No account is given of any operation for their removal. The picture of the knee-joint on page 536 shows the tendon of the biceps flexor cruris passing apparently *under* the long external lateral ligament.

The illustrations as a rule are excellent. There have rarely been produced more vivid and lucid drawings than those of the muscles shown in this book. The pictures of the neck, thorax, and abdomen are also excellently reproduced. As an appendix a number of valuable illustrations are given of frozen sections through the trunk and limbs.

The author is fully justified in the statement made in the preface to the effect that the book is suggestive rather than absolute—and in his hope that it will appeal to the practising physician and surgeon as well as to the student. After a careful perusal of the work, one has every confidence in recommending it to the student in anatomy and surgery. It will be of great service also to the demonstrator of anatomy and young teacher of surgery, from its value in pointing incisively the applicability of anatomical data to surgical problems. For the operating surgeon it has less value. He will naturally appeal either to the cadaver itself or to a systematic textbook of anatomy for the information he seeks. The modern military orthopædic surgeon will not find here the detail or accuracy needed to enable him to perform operations on tendons, joints, or peripheral nerves.

Military Surgery. By Dunlop Pearce Penhallow, S.B., M.D. Harvard. Second edition. Pp. 555. 1918. London: Henry Frowde and Hodder & Stoughton. 21s. net.

The rapid changes in military surgery have necessitated many alterations of view, and it is therefore not surprising that the author has found it necessary to issue another edition. When dealing with the previous edition, we called attention to some of the more important omissions. In the volume before us these have been to a great extent supplied, and a much more complete picture is presented of the state of military surgery, with a tendency to dwell upon treatment in this country, rather than that in the forward areas of the war. Some sections are rather inadequately treated, notably that dealing with injuries to blood-vessels, in which the importance of the decision whether ligature or arteriorrhaphy shall be employed in certain cases does not appear to be recognized. Possibly this is because so little has appeared upon this subject in English surgical literature as contrasted with that of the allied and enemy forces. The important subjects of fractures of bones and wounds of joints receive extended notice, and due stress is laid upon the importance of complete primary treatment if a good result is to be obtained.

Surgical Treatment: A Practical Treatise on the Therapy of Surgical Diseases, for the use of Practitioners and Students of Surgery. By James Peter Warbasse, M.D., F.A.C.S. In three large 8vo volumes and separate desk index volume. Vol. I. Pp. 947, illustrations 691. 1918. Philadelphia and London: W. B. Saunders Co. £6 6s. per set.

This work, dealing with surgical treatment in three large well-illustrated volumes, is one of great importance. It combines the advantages of an expensive *System* of encyclopædic scope with those of a book written by a single author. The present volume deals with general principles, anæsthesia, operative technique, surgical infections, blood-vessels, bones, joints, muscles, and

nerves. It includes a description of all the most important surgical operations, together with the preparatory and after treatment suitable for each. The descriptive matter and illustrations are extremely clear, and for reference purposes every important method of surgical treatment is easily looked up.

Naturally the author of such a book, being anxious to represent every method, is apt to overlook the necessity for a critical examination of each; for example, in the operation of arthroplasty for knee-joint ankylosis, the procedure is described very much as that for a bunion, with the mere remark that the operation on the knee "gives most gratifying results."

The preliminary articles on general principles and operative technique are good and complete; that on anæsthesia being a very useful presentation of various modern methods. The description of intratracheal anæsthesia is, we think, the weakest part of this section, the value of the procedure in oral surgery not being given due weight. Spinal anæsthesia and its various modifications, on the other hand, are dealt with at disproportionate length. The articles on wound treatment and infections are brought into line with recent work by the inclusion of the Carrel-Dakin and other methods of war-wound treatment. Direct transfusion of blood is well and fully described, together with both the modern operations for the suture of blood-vessels and the more classical operations for ligature of the main trunks.

The chapters on fractures and bone operations are full of valuable information, although here again, for the sake of completeness, methods are included which might better have been left out—such, for example, as the so-called extension of the fractured femur combined with the use of a long Liston splint. Albee's methods of bone-grafting are given due prominence, together with various modern methods of open treatment of fractures. But the general principles of the treatment of fractures by extension methods are neither clearly appreciated nor adequately described, whilst a great number of odd methods are illustrated.

The book is, however, of the greatest possible value as a work of reference, containing, as it does, a great wealth of information and illustrations.

Burns and their Treatment, including Dermatitis from High Explosives. By J. M. H. Macleod, M.A., M.D. Small 8vo. Pp. 176, illustrated. 1918. London: Henry Frowde and Hodder & Stoughton. 6s. net.

The direct outcome of war experience, and the result of special study of the subject—including dermatitis from high explosives—this work appeals to readers by reason of its brevity, clarity of exposition, and utility. The author has sifted the literature of the subject thoroughly, and has presented not only the experience and apparatus of others, but his own practice and advice. Each section of the book deals in a plain matter-of-fact way with its subject matter, and carries conviction. There is a very good index, and the references are detailed and complete, so that in addition to its practical side, material for research work is provided. It is therefore from all points of view eminently useful.

War Wounds of the Lung: Notes on their Surgical Treatment at the Front. By Pierre Duval. English translation. 1918. Bristol: John Wright & Sons Ltd. 8s. 6d. net.

Pierre Duval was among the first to recognize that gunshot wounds of the lung should be treated by the same energetic measures as were being applied to gunshot wounds of other parts of the body, and that without such active intervention it would be impossible to lower materially the high mortality—due especially to infection—that was occurring in these cases. His attitude is expressed in the following paragraph: "It is the first principle in war surgery to prevent infection of wounds, and the only method of preventing sepsis in gunshot wounds is to operate on them, to remove all foreign bodies, and to excise as far as possible all necrotic tissue. It is only logical to think that the really effective treatment of infection in the lung, and of its usual complication, infection of the pleura, is preventive treatment by removal of foreign bodies and direct treatment of the lung wound." (p. 46 of the English translation).

Duval published *Les Plaies de Guerre du Poumon* in 1917, and this has now been translated into English. The book consists of some 100 pages and a few instructive illustrations. It is clearly and concisely written, and is devoid of all superfluous matter. The facts and the deductions based on these facts are set out in logical order and in a most straightforward and convincing manner. The English translation, the type, and the printing are all three excellent. The book is undoubtedly one which should be read by all who have to treat lung injuries, whether in the field or at home, as a knowledge of the matter contained therein is essential to success.

Commozione Cerebrospinale. By Dott. F. Pedrazzini. Small 8vo. Pp. 170, with 13 illustrations. 1918. Milan: Ulrico Hoepli. L. 3.50 net.

This little book emphasizes the reality of cerebrospinal lesions following concussion. The physics of the skull and vertebral column are first considered, then the compensatory mechanism provided by the elasticity of the spinal dural sac, the compressibility of the perimeningeal space in the vertebral column, and the slight compressibility of the brain and cord. These factors afford a large degree of protection; but when the force is applied instantaneously, there may not be

time for their action. Then the force will be transmitted by the incompressible cerebrospinal fluid direct to the compressible cerebrospinal matter. Experiments showed that hæmorrhages might occur in most parts of the brain, but especially in the pons and medulla, while in the cord the principal effects of spinal concussion were systemic degeneration and circumscribed foci of softening. After the examination from the literature of a number of cases of post-traumatic paralyses, the same principles are applied to the question of shell-shock. In the author's words: "In the neighbourhood of the explosion of large projectiles the pressure of the atmosphere on the surface of the body compresses the thoracic and abdominal cavities and the soft parts of the neck, and causes a reduction in size of the large veins and of the auricle, and a sudden obstruction to the returning flow of the blood. This gives rise to a sharp shock within the cranio-vertebral cavity, due to regurgitation of blood, with variations in the capacity of the elastic dural sac and of the volume of its contents, and consequently the production of waves of pressure and movements of the liquid in the arachnoid reservoir, analogous to those caused by traumatic deformations within the limits of the elasticity of the skull and vertebral column." Lumbar puncture should be used in these cases as a means of treatment as well as diagnosis.

The book is a serious contribution, based on experimental and clinical evidence, to a subject of general interest in these days.

Lessons from the Enemy (Medical War Manual, No. 5). By JOHN R. McDILL, M.D., Major M.R.C., U.S. Army. 8vo. Pp. 262 + xvii, illustrated. 1918. Philadelphia and New York: Lea & Febiger. 6s. net.

IN a philosophic foreword, the author gives a bird's-eye view of the World War and of the part played therein by the medical profession. There follows a description of the German medico-military organization, ranging from the rank and pay of medical officers, to the equipment of hospitals, hospital trains, and base hospitals. In the treatment of gunshot wounds he declares himself an advocate of the Carrel-Dakin method, and gives an account of the German equivalent or imitation thereof. Concluding chapters deal with volunteer nursing under the Red Cross, re-education of the 'war-disabled,' orthopædic hospitals and workshops, and finally with artificial limbs. It may be confidently stated that within a small compass this book contains a quantity of information which is not easily obtainable from other sources.

Principles of Surgical Nursing: A Guide to Modern Surgical Technique. By FREDERICK C. WARNSHUIS, M.D., F.A.C.S. Large 8vo. Pp. 277, with 255 illustrations. 1918. Philadelphia and London: W. B. Saunders Co. 12s. net.

THIS small book is a successful attempt to give detailed practical directions as to a nurse's duties in the operating theatre, at private houses, and in the wards.

The author has embodied the essential details of everyday practice, with a sufficient amount of theoretical explanation to justify the same. Such a book is always open to the criticism that by laying down too great an amount of detail a system is taught which does not represent the practice of more than a single individual. But it is probably better for practical purposes to describe accurately the practice of one man, than be content with vaguely outlining principles which all are agreed upon. The book certainly inculcates the idea of a keen surgical conscience, and this principle is perhaps the most important that can be taught by such a work.

We think that no good purpose would be served by criticizing details of the author's technique, because as has already been stated this is largely a matter of individual practice. With recent experiences of war surgery vividly in our minds, we think the greatest need of this book is to describe methods of dealing with emergencies, and the organization of nursing of numbers of septic cases. The author contents himself with describing the technique of the operating room, post-operative emergencies, anæsthesia, plaster-of-Paris splints, the operation for appendicitis, and a few other less important details. It is doubtful whether the great wealth of photographic illustrations adds very much to the value of the book.

The Treatment of War Wounds. By W. W. KEEN, M.D., LL.D. Second edition. 8vo. Pp. 276, with 53 illustrations. 1918. Philadelphia and London: W. B. Saunders Co. 8s. 6d. net.

THE best testimony to the value of this work is the fact that its first edition has been exhausted in six months. This has been due no doubt to the great reputation of its author. The present edition has been largely re-written, in order to deal with the subjects of shock, the Carrel-Dakin and other methods of wound treatment, fractures, tetanus, wounds of the head, chest, and joints, and gas gangrene. The book is so short, and consists so largely of abstracts and summaries, that it cannot be regarded as more than a brief *résumé* of recent work. It is to be regretted that such an inaccurate picture as *Fig.* 21 should ever have been drawn and reproduced. It represents a Balkan splint so arranged that the thigh sling could never remain in the position indicated.

SIR WILLIAM FERGUSSON.

1808–1877.

Born at Preston Pans on March 20, 1808, the son of James Fergusson, of Lochmaben, Dumfriesshire, William Fergusson was educated at the High School, Edinburgh, and after spending two years in a lawyer's office, he began to study medicine at Edinburgh at the age of seventeen. He soon attracted the notice of Robert Knox—then at the height of his fame as a teacher of anatomy—by his mechanical ingenuity and the excellence of his dissections. Knox appointed him a chief assistant in the dissecting rooms at the Old Surgeons' Hall, where four hundred students attended daily. In this position Fergusson showed such a decided bent for surgery, that Knox commissioned him to give a special course on surgical anatomy—then a new feature in anatomical teaching. In 1833 this course had proved so great a success that Dr. John Reid joined Knox and Fergusson, paying £250 for the privilege, and receiving a third share of the proceeds. In 1828 Fergusson became a Licentiate and in 1829 a Fellow of the Royal College of Surgeons of Edinburgh. In 1831 he was appointed Surgeon to the Edinburgh Royal Dispensary, and in 1836 he was elected Surgeon to the Royal Infirmary. By this time he was sharing with Syme the chief surgical practice in Scotland.

Rendered independent by his marriage in 1833 with Helen Ranken, daughter and heiress of William Ranken, of Spittlehaugh, Peebles-shire, he came to London in 1840 on his appointment as Professor of Surgery at King's College and Surgeon to King's College Hospital. He was admitted a Member of the Royal College of Surgeons of England after examination in 1840, and was elected an Honorary Fellow of the College in 1844, living at first at 8, Dover Street, Piccadilly, and afterwards at 16, George Street, Hanover Square. He quickly attained a large surgical practice, which became still larger after the death of Robert Liston in 1847. He was appointed Surgeon in Ordinary to Prince Consort in 1849, Surgeon Extraordinary to the Queen in 1855, and Serjeant Surgeon in 1867, having received a baronetcy in January, 1866. In 1861 he was elected—not without strenuous opposition—a Member of the Council of the Royal College of Surgeons of England; but he was soon appreciated at his proper worth, for he was elected a Member of the Court of Examiners in 1867, and after serving various minor offices, was chosen President in 1870. He died of Bright's disease on Jan. 10, 1877, and was buried at West Linton, near Edinburgh, leaving two sons, Lady Fergusson having predeceased him.

Whilst he was still living in Edinburgh, Fergusson became strongly imbued with the belief that it was often possible to preserve diseased tissues by careful operative procedure, and that it was especially desirable to do so in cases of joint disease, where it was the habit of his colleagues to amputate. In this he followed the sound teaching of Jeffray of Glasgow, Crampton in Dublin, and Roux in Paris. By precept and example he soon reduced the resection or excision of joints to a system, under the general title of 'conservative surgery.' He was amongst the first to excise the upper jaw; in 1845 he revived the operation of excision of the head of the femur; in 1847 he performed the operation of excision of the scapula; and from 1850 onwards he excised the knee as a routine procedure. Of excision of the upper or lower jaw, he says, "I have recommended the sitting posture as being the most convenient, for the blood is thus permitted to escape by the mouth. Sometimes a patient will faint, and must then be laid on his back—indeed, whether or not, it is always best to do so as soon as the disease has been removed. It has often happened that these proceedings have been retarded by sickness and vomiting; and, considering their severity, I need scarcely point out the propriety of having wine at

hand, contained in a vessel (such as a teapot) with a spout of sufficient length to permit the contents being poured into the back of the mouth."

Operations of this magnitude upon conscious patients could only be undertaken by men of great physical strength and immense dexterity, and it was in these two points that Fergusson and Liston excelled their colleagues, though the operating surgeons in days before the introduction of anæsthetics were always large and powerful men. Yet, with all his strength, Fergusson carried out to perfection the delicate operations for hare-lip and cleft palate. Of cleft palate he writes, " I need scarcely say that such an operation can be done only in the soft palate ; but should the fissure extend further forward, as it often does more especially in instances of hare-lip, the aperture in front can be afterwards closed with an artificial plate. Unless the patient is remarkably steady and determined to permit the operation to be finished, it will be needless to attempt it ; and as such fortitude is not to be expected before the age of puberty, it will seldom happen that the surgeon's services are required before this period. Even when he has finished the proceedings in a most satisfactory manner, he must not be over sanguine of a fortunate result. Every precaution must be taken to prevent movement of the palate ; the patient should partake of a meal immediately before the operation, and for the first two days should only swallow a little liquid, which he should allow to pass into the pharynx with the smallest possible drag on the stitches ; at other times he should not permit the saliva even to pass backwards. The stitches should be carefully cut out on the second or third day, and on no account whatever should he partake of solid food until all risk of the wound tearing open has passed away." From such small beginnings, Fergusson elaborated a complete operation, with division of the levator palati, and closure of the hard palate by osteotomy of the roof of the mouth.

Throughout his life Fergusson showed himself a first-rate demonstrator and surgeon, but never a good lecturer. He was an excellent colleague and true friend, ready to give credit where it was due, and free from the envy and self-seeking which marred the characters of too many of his generation. His name came early into public notice in connection with the murders committed by Burke and Hare in Edinburgh at the end of the year 1827. These miscreants murdered their victims to supply the anatomical rooms at Edinburgh. Robert Knox was willing to give the highest price for subjects, and it fell to the lot of Fergusson as one of the chief assistants to accept the bodies thus received. He shared this duty with his two colleagues, T. W. Jones and Alexander Miller. Feeling ran high ; Knox and his assistants were roundly abused, and were threatened with personal violence at the hands of the mob. In the end the assistants escaped, but the professional career of the master was ruined.

The portrait of Sir William Fergusson is from a photograph kindly lent by Sir Berkeley G. A. Moynihan, K.C.M.G., C.B.



SIR WILLIAM FERGUSSON.

From a photograph in the possession of Sir Berkeley G. A. Moynihan, K.C.M.G., C.B.

THE PATHOLOGY OF GUNSHOT WOUNDS OF THE SPINE AND SPINAL CORD.

By Colonel WILLIAM THORBURN, C.B., and Major GEORGE RICHARDSON, R.A.M.C.

Until the outbreak of the present war, our knowledge of the pathology of fractures and allied injuries of the spine was practically confined to that of simple fractures or 'fracture-dislocations' produced by the ordinary injuries of civil life, the most common form, and that which has been most fully investigated, being the type due to over-flexion of the whole back. Other injuries were in peace time regarded as unclassified rarities, and even in the wars of the last quarter of a century we know of no collection of pathological material illustrative of gunshot wounds. To a large extent our knowledge of fractures in general has been extended and modified during the last four years; but it can hardly be said that this applies to the spine, its investigation having been retarded by two main factors, the difficulty of obtaining satisfactory skiagrams, and the overshadowing of the bony lesion by the serious nature of the resulting visceral injury.

Under these circumstances it has appeared to us that it might not be without value to collect and compare a number of cases which we have investigated. The material at our disposal consists of post-mortem specimens prepared by one of us in a base hospital in France, and of operative findings by another of us in various theatres of war. The two series of cases are mutually illustrative, and although the exigencies of military service have rendered many of our notes very incomplete, and led to the loss of many records, we have endeavoured to give at least the outlines of a picture which may be filled in by others. The dried specimens to which reference will be made and which are here illustrated, have all been forwarded to the Museum of the Royal College of Surgeons of England.

In considering the conclusions arrived at, a few reservations must be made. The experience of the individual in war time is determined by his position in the war area, and may differ widely with his proximity to the front or to the base. All our observations have been made at advanced bases, the majority in a French seaport, others in Salonika, Mudros, or Malta, and a very few, during the early period of the war, in England. In effect, this implies that we have seen little of the most serious cases, which die before reaching the base, and even less of the least serious cases, which have been evacuated to England. Again, the actual conditions of warfare greatly modify the nature and frequency of the wounds produced. During the last seven months of open warfare in France we have seen a far larger proportion of injuries to the spinal cord than in the earlier days—a fact due partly, perhaps, to the absence of cover, and possibly also to the large proportion of rifle or machine-gun bullet wounds as compared with wounds from shells or bombs. It is at least probable that a great proportion of shell wounds of the spine never reached base hospitals. With regard to operative findings, it is also to be noted that as operations were performed in a very limited number of selected cases, they are in no sense illustrative of the comparative frequency of the lesions found.

On all these grounds we have thought it useless to attempt any estimate of the relative frequency of various types of wound, and we shall confine ourselves to a record of cases, dealing principally with injuries to the bones.

INJURIES TO THE VERTEBRÆ.

Certain general characteristics are at once apparent. While in civil life by far the most common injury of the spine is a fracture of one or more vertebral bodies, with displacement of the whole column, generally in the direction of flexion, our specimens show

very few in which the central mass is seriously involved, and none in which any angular curvature was or could have been produced. It must not, however, be concluded that direct impact upon the bodies of the vertebræ is as uncommon as here appears. Such direct impact will usually imply a coincident injury of thoracic or abdominal organs, and these cases would be little likely to arrive even in casualty clearing stations.

Another point which immediately attracts our attention is the wide distribution of fractures throughout several vertebræ, and the frequent presence of what we may call 'remote fractures'—of cracks and fissures well removed from the point of impact. Many of these remote fractures may be due to the general disruptive or divulsive action of gunshot wounds as seen in other regions ; but many are probably due to the wrenching away of bony prominences by the strong ligaments attached to them. In this way a powerful impact upon a single spinous process may blow it away, and carry in its course ligaments which, instead of themselves tearing, will wrench off fragments from their distal bony attachments. Hence we constantly find remote cracks and fissures such as are hardly met with in other regions of the body. The same tendency is shown in the remote fractures of spinous processes and laminæ accompanying ordinary 'fracture-dislocations,' and these widespread effects are almost characteristic of injuries to the spine.

We also note, as was to be expected, two types of fracture, often seen in different parts of the same specimen. On the one hand, we meet with abrasion, crushing, and perforation in areas subject to direct impact ; in many such cases bone is entirely pulverized and destroyed, the destruction being very marked in the case of the loose cancellous tissue of the bodies and lateral masses. On the other hand, we find clean cracks and fissures, often with little or no displacement of fragments, although it is practically certain that there has been at least a temporary displacement, associated with that *recoil* which is so marked a characteristic of spinal injuries, and which renders the visible osseous lesion little indicative of the seriousness of the crush inflicted upon subjacent nervous structures.

In connection with cracks and fissures, we may also note that, as each vertebra constitutes a bony ring, a fracture at any one point tends to be associated with a second fracture which will roughly lie diagonally opposite to it. It is thus rare to find a crack of one lamina only, although outlying processes may be detached by single fissures. It is also not very common for cracks and fissures to extend through the strongly-built pedicles ; injuries which might have produced such lesions expend their impact upon the loose cancellous tissue of the vertebral body near the seat of origin of the pedicle ; thus we have a 'seat of election,' the pedicle being wrenched away just below its base rather than split through its compact bony tissue (see *Figs.* 412, 415, and 417).

In connection with the osseous lesions, we may also note one or two points with regard to the *lodgement of foreign bodies*. In many cases these have completely transfixed the spine, and either lodged in remote parts or passed out through an exit wound. Skiagraphy is here of value in diagnosis, as the track of the missile can often be traced by bright spots due to minute fragments of metal left in its passage through the bone, and thus we can detect spinal injuries not otherwise recognizable during life.

Apart from such minute particles, impaction of metal fragments is not common in the arches and processes of the spine, but usually occurs in the bodies of the vertebræ or inside the vertebral canal. So far as the dense, brittle, and rounded processes are concerned, it is obvious they do not lend themselves to impaction, unless, as in *Case* 17 (*Fig.* 425), the fragment be of sufficient size and low enough velocity to become engaged between several processes. On the other hand, we have seen a good many cases of impaction, especially of shrapnel bullets, in the posterior part of the vertebral bodies. *Figs.* 410 and 411 are illustrative, and others have been met with at operation. In some of these the bullet has apparently passed between the laminæ without producing any fracture thereof.

Lodgement in the vertebral canal has been met with rather frequently at operation ; but naturally such frequency is much influenced by the selection of cases. It is important in this connection to remember that a round smooth object like a shrapnel bullet may descend the canal. This is clearly shown in *Case* 5 (*Fig.* 412 *a* and *b*). In another case one of us removed a bullet from the lumbar canal which had twice previously been sought

for at too high a level; and we know of an instance in which an attempt to remove a bullet from the level of the first cervical vertebra resulted in its slipping downwards to the third. In all the cases which we have met with the bullet has slipped down inside the theca, and not between the theca and the bone.

On passing to the detailed examination of our specimens, we have found considerable difficulty in making any useful classification into groups; but we think that they may be regarded as falling under two main headings—viz., those in which the missile has impinged upon the spine at something approaching to a right angle, and those in which it has inclined to glance along or across the line of the vertebral column. Although recognizing that such distinction must be somewhat arbitrary, we shall therefore speak of (1) *Fractures by direct impact*, and (2) *Tangential fractures*.

We shall then find that fractures due to direct impact are divisible into those in which the missile has lodged in the spine, and those in which it has perforated and passed beyond it; while the 'tangential' fractures are again roughly divisible into those in which the wound runs along or parallel to the vertebral column, and those in which it tends to cross it at a wide angle.

1*a*. **Cases of Fracture by Direct Impact, with Retention of the Missile in the Spine.**—These vary from injuries which are almost trivial, so far as the bones are concerned, to those in which the damage is extreme; there being no necessary relation between the severity of the fracture and that of the injury to the cord.

Case 1 is an example of a perforating injury which is of the slightest possible extent. The patient died twenty-five days after injury. The right 5th cervical lamina presented a minute puncture. Beneath this was a small healed opening in the theca, which was here adherent to the spinal cord. At a slightly higher level, and lying under the 4th cervical lamina, a spicule of bone was embedded in the posterior fibres of the spinal cord, which were in part divided; while still higher a minute fragment of metal was embedded in the left side of the theca. The specimen from this case, to which we shall refer later, is in the College of Surgeons War Museum, and is not at present accessible to us.

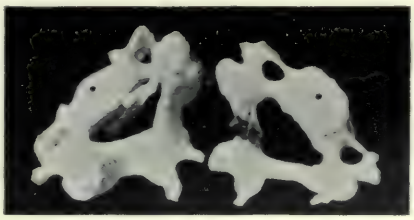


FIG. 409.—*Case* 2. The 4th and 5th cervical vertebræ. The 5th (right) shows fragment of metal *in situ*; the 4th (left) the depressed spicule of bone.

In *Case* 2 (*Fig.* 409) we find a similar condition of slight bony injury with severe damage to the spinal cord. A fragment of metal about the size of a dried pea has impinged on the upper margin of the right 5th cervical arch, where it remains lodged, making an aperture which will scarcely admit a lead pencil, but driving forward into the vertebral canal a fragment of bone half an inch long, which pierced the theca and partially divided the spinal cord.



FIG. 410.—*Case* 3. Metal embedded in body of 2nd lumbar vertebra. Incomplete fracture at base of spinous process.

Case 3 (*Fig.* 410) illustrates a condition which we have seen more often upon the operating table. A piece of metal has passed between the 1st and 2nd lumbar arches, and lies embedded in the middle line of the body of the 2nd lumbar vertebra. Before entering, it has slightly abraded the tip of the 2nd lumbar spinous process, and has caused an incomplete crack at its base; but, as in several cases of this type, there is no substantial injury of the laminæ, and operation would not have shown any fracture.

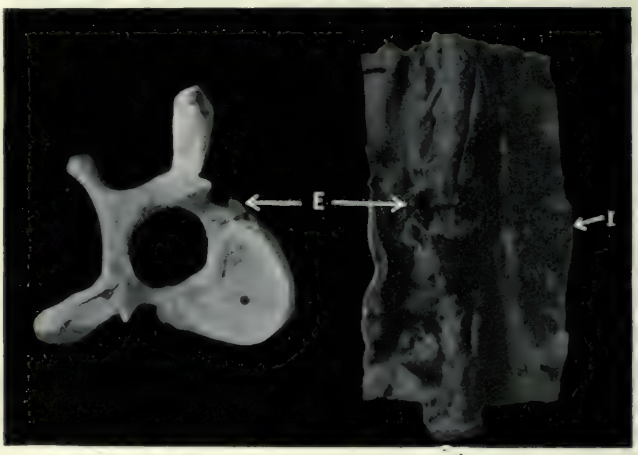
An example of impaction of a rifle bullet, which appears to be less common than that of shrapnel or

of irregular fragments, is seen in *Case* 4 (*Fig.* 411), in which the patient survived for a month, dying eventually from pneumonia and empyema. In the posterior part of the 7th dorsal vertebra is jammed the casing and part of the contents of a rifle bullet, the metal occupying the anterior half of the vertebral canal. Some fragments had entered the right lung and emerged through the right axillary line. The bullet appears to have entered the base of the spinous process on the left side, causing only very slight destruction of bone; but a clean crack runs through the left upper articular process and the base of the right pedicle, so that almost the whole of the bony arch was detached, but left *in situ*.



FIG. 411.—*Case* 4. Portions of rifle bullet embedded in body of 7th dorsal vertebra. The lead core is in the centre, with portions of casing on each side.

Case 5 (*Fig.* 412, *a* and *b*) shows equally through how small an aperture the vertebral canal is often perforated. A shrapnel bullet has slightly grooved the left pedicle of the 3rd dorsal vertebra, causing a crack which runs down just in front of the junction of this pedicle with the body. Crossing the vertebral canal, the bullet has then impinged upon and slightly abraded the right lamina, from which, rebounding, it has fallen into the canal. The theca was penetrated at the point of entrance on the left side, but not at the point of recoil on the right side. The bullet thus lay inside the thecal canal, and had fallen downward an inch and a half from its point of entry. The cord shows two points of crushing (*Fig.* 412, *a*), one at the point of entry, and the other about a quarter of an inch lower down at the point of reflection.



a *b*

FIG. 412 (*a*, *b*).—*Case* 5. (*a*) The 3rd dorsal vertebra. Point of entry of bullet is seen at left pedicle; point of impact was at opposite side. (*b*) Shows the theca and cord; a shrapnel bullet is seen low down on the left side. (E) Point of entry. (I) Point of impact.

Case 6 (*Fig.* 413, *a* and *b*) is in strong contrast with the above. The wound, due to an expanding rifle bullet, has been received over the 3rd lumbar vertebra. The spinous process and laminæ of that vertebra are completely pulverized, and its right transverse process is blown away; large splashes of lead occupy the bony masses of the superior and inferior articular processes on the right side. Another piece of lead and part of the casing

lie in the back of the body of the vertebra. This specimen presents also numerous remote bone injuries. Extensive cracks separate two large pieces from the spinous process and

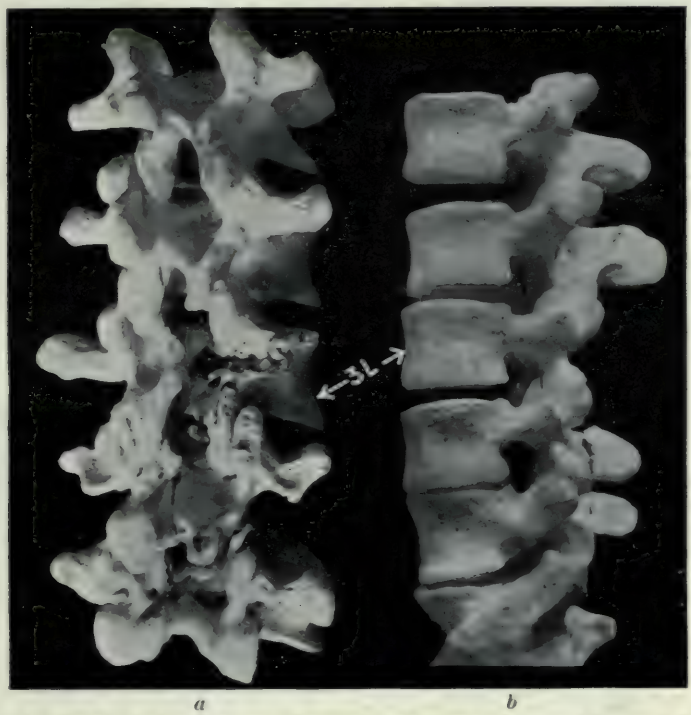


FIG. 413 (*a*, *b*).—*Case* 6. (*a*) Lumbar spine. Extensive bony damage and scattered fragments of metal. (*b*) Is a lateral view showing extent of bony damage.

articular process of the 2nd lumbar vertebra, and a crack runs through the base of the left pedicle of the 3rd. The spinous processes of the 4th and 5th, and the upper articular process of the 4th, are detached. So extensive an injury can hardly have been due to direct impact, even by fragments of an expanding bullet, and the result is probably due to impact upon the strong spinal ligaments, which have torn away outlying processes above and below the seat of impact.



FIG. 414.—*Case* 7. Cervical spine. Fracture of 5th and 6th arches.

1*b*. **Cases of Fracture by Direct Impact, with Complete Perforation of the Spine.**—These resemble the previous group in the great variations in the severity of the injury. In some this is extraordinarily slight, and would hardly seem commensurate with the severe effect produced; in others there is much bony damage, which again may be localized to the region of direct impact, or may be associated with cracks and fissures at a distance therefrom.

Case 7 (*Fig.* 414) is illustrative of the slightest form of bony lesion. The patient was admitted to hospital in a dying condition, with a much-distended abdomen and a lodging wound with gas gangrene of the right thigh and buttock. No spinal injury was suspected, but death

occurred within an hour of admission. At the post-mortem examination, the distention of the intestines and bladder without any signs of inflammation led to a careful examination of the spine. There was found a minute penetrating wound, with entrance behind the left sterno-mastoid muscle, and exit on the right side at the same level. On laying this open there was exposed a fracture of the left arches of the 5th and 6th cervical vertebræ, with no displacement of bone, although fragments as shown in *Fig.* 414 were separable after maceration. Around the untorn theca was some blood-clot, and the spinal cord showed a central hæmorrhage. It is clear that we have here a case in which the two small bony fragments were momentarily displaced, but recoiled to their original position. It is, however, very doubtful whether this case should be regarded as having arisen from a direct impact or from a tangential blow.



FIG. 415.—*Case* 8. Showing point of exit of shrapnel bullet through pedicle and body of 10th dorsal vertebra.

Case 8 (*Fig.* 415) illustrates a more common condition, in which the wound has passed directly through the spine. A shrapnel bullet entering the right loin, and coming to rest below the left kidney, has passed through the right 10th and 11th dorsal articular processes, and outwards through the pedicle of the 10th dorsal vertebra. The holes of entry and of exit are very cleanly drilled through the soft bone here encountered, but there is a crack through the right 10th dorsal pedicle and through the remains of that of the left side, so that the entire bony arch of the injured vertebra was separable, although retained in position. The theca and spinal cord were completely cut across.

Closely similar is *Case* 9 (*Fig.* 416), in which a rifle bullet passed from the right side of the neck through the 4th and 5th dorsal vertebræ and left scapula. Impact has here occurred on the right side of the body of the 4th dorsal vertebra, of which part is pulverized, while the left half of the 5th dorsal vertebra, with its pedicle, and the transverse process of the 6th, are also lost. There is a long crack, without displacement, through the spine of the 5th. The theca would clearly lie away from the track of the bullet, but it presented a small tear behind the 5th cervical vertebra, and the spinal cord was diffluent over a wide area.



FIG. 416.—*Case* 9. Destruction and loss of substance of body of 5th dorsal vertebra.

The two following cases differ from those already described, in that the wounds inflicted are less sharply drilled through the bones and are associated with more extensive splintering.

In *Case* 10 (*Fig.* 417), the missile, of which the nature is unknown, had passed through the right lung and the liver, impinging on the body of the 11th dorsal vertebra. It here passed through the front of the right lamina ; but instead of completely pulverizing the soft bone, it has blown out two more or less triangular fragments. It then destroyed the left arch. Subsidiary cracks involve the spinous process of the 11th dorsal vertebra, the superior articular process of the 12th,

and the 'seat of election' in front of the right lamina of the latter, all of which are probably due to the indirect impact from the vertebra above.

Still more marked is the extensive fracture in *Case* 11. A rifle bullet, passing through the apex of the right lung and the trachea, has penetrated the bodies of the 2nd and 3rd dorsal vertebræ, passed on between the 3rd and 4th, and made its exit a little to the left of the 4th dorsal spine. The extensive secondary injuries are best appreciated from the annexed photograph (*Fig.* 418, *a* and *b*).

Looked at from the front, we see: (1) Three large separated fragments of the 2nd dorsal body, with a hole between them; (2) A similar condition of the 3rd dorsal vertebra; (3) A vertical split down the centre of the body of the 4th dorsal. From behind, we see that the bullet in its descending course has spared the laminæ and spine of the 2nd dorsal, but has blown away the spine and fractured both arches of the 3rd. It has also broken three large fragments of the left lamina, the arch, and the spine of the 4th dorsal vertebra.

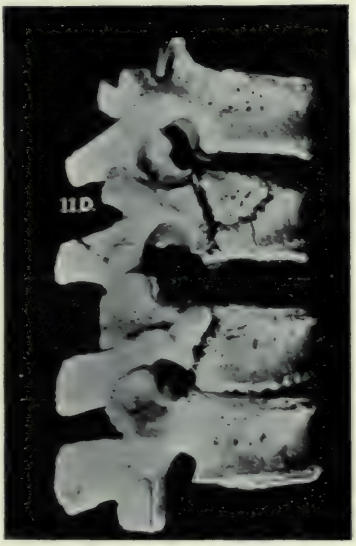


FIG. 417.—*Case* 10. Fracture of body of 11th dorsal vertebra, and fracture of 12th dorsal at 'seat of election.'

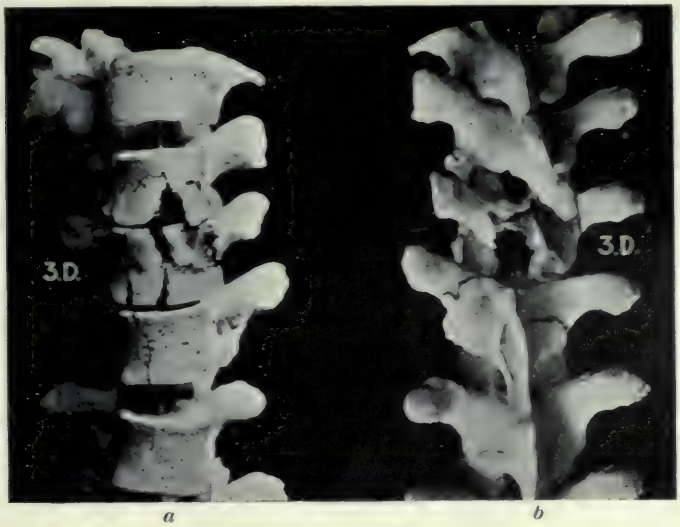


FIG. 418 (*a*, *b*).—*Case* 11. (*a*) Shows the entry wound at the bodies of the 2nd and 3rd dorsal vertebræ. (*b*) Shows the exit wound, involving chiefly the 3rd dosal vertebra.

2. Cases in which there has been a Tangential Blow upon the Spine, and in which the Vertebral Canal is, as a rule, not penetrated, either by the Missile or by Fragments of Bone.

Case 12 (*Fig.* 419) is an example of the slightest degree of this type of injury. The patient was admitted with paraplegia and anæsthesia extending upwards to about midway between the pubes and the umbilicus, and with abdominal symptoms for which a laparotomy was performed. The abdomen contained a quantity of blood, and the

intestines were distended. The patient became so collapsed that the operation was not completed, and death occurred very shortly afterwards. The autopsy showed that a machine-gun bullet had entered to the left of the lumbar spine, and come to rest in the right lobe of the liver. The left inferior articular process and the spinous process of the 11th dorsal vertebra had been carried away. The theca was uninjured, but at the level of impact the spinal cord was so much destroyed and thinned as to be almost divided.

Case 13 (*Fig.* 420) is a more severe example of a similar condition. A rifle bullet had entered the back of the neck on the left side, and was



FIG. 419.—*Case* 12. Slight injury to spinous and to left inferior articular processes of 11th dorsal vertebra.



FIG. 420.—*Case* 13. Injury to right side of 3rd cervical vertebra.

resting subcutaneously on the right side of the neck, having struck the 3rd cervical vertebra in its passage. The 2nd and 4th cervical vertebræ are quite uninjured. As regards the 3rd, the spinous process, with the lower margin of the left lamina, the lower right articular process, and the right transverse process, are all blown away. There is no narrowing of the vertebral canal, and no loose bony fragments were found therein : but the theca was widely torn and the spinal cord crushed at the site of the lesion.

The two following cases differ in that the tangential blow has taken a vertical rather than a horizontal direction.

Case 14 (*Fig.* 421) was admitted with a wound over the left shoulder, and presented a metal fragment lying opposite the middle of the left sternomastoid muscle. From the left transverse process of the 6th cervical vertebra has been blown away a small fragment of bone, opening the foramen for the vertebral artery. The 5th cervical vertebra shows a more extensive destruction, due to several clean cracks involving the bulk of the lateral mass. In the 4th vertebra, the lower articular process is blown away. In the 3rd, the lateral bony mass is completely detached by clean fissures, but is not displaced : in this vertebra there is also a clean fracture through the right lamina. There was a small amount of blood-clot around the theca, but the latter and the spinal cord showed no macroscopic change, although, as we shall see hereafter, there was a hæmatomyelia at the seat of injury (*Fig.* 422).

Case 15 (*Fig.* 423) is also an example of an extensive glancing blow. The missile entered above the middle of the posterior border of the right sternomastoid muscle, and escaped from the left side through the outer end of the supraspinous fossa of the scapula. Five vertebræ are affected, as follows : In the 5th cervical there is a separation of the spinous process, and a small crack in the right transverse process. In the 6th cervical

the spinous process is destroyed down to its base, while there is a small crack in the right lamina. The 7th cervical shows still more complete destruction of the spinous process



FIG. 421.—*Case* 14. Injury to 3rd, 4th, 5th, and 6th cervical vertebræ. The injury to the spinous process of the 7th is an artefact.

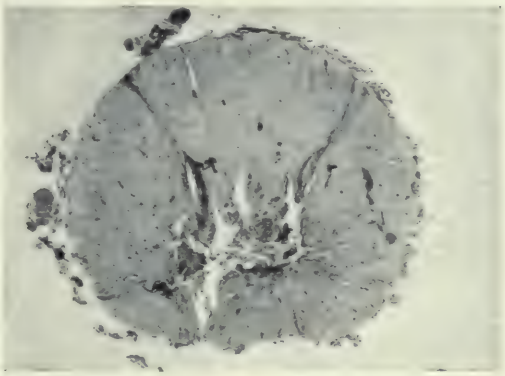


FIG. 422.—*Case* 14. Section showing area of maximum hæmorrhage.

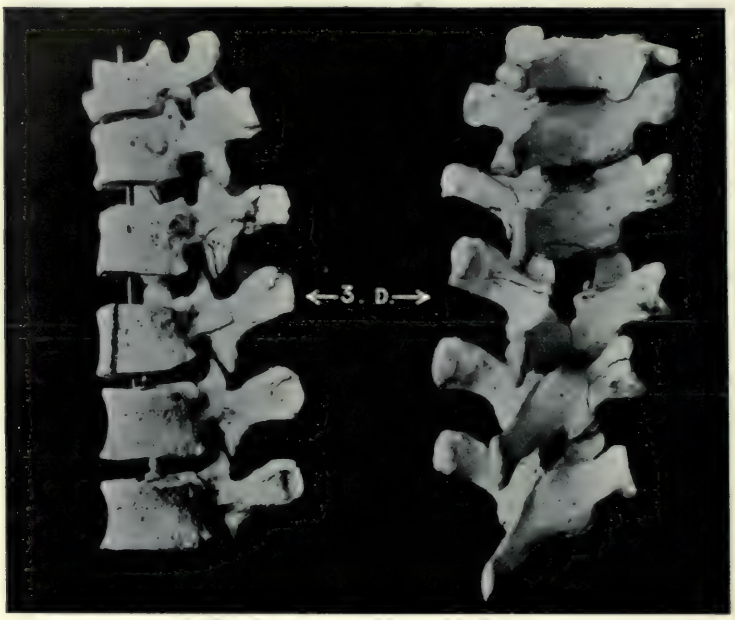
and of the inner aspect of the lamina. The 1st dorsal has a long horizontal crack across the lamina, so that a large part of the right lamina, with the spinous process, is separated, although not displaced. Finally, the 2nd dorsal vertebra presents a fracture through the outer end of the left lamina. The oblique track of the missile is thus clearly shown, the main impact having occurred about the base of the 7th cervical spinous process, where a small fragment of metal is embedded. At this point minute fragments of bone had been driven inwards and had lacerated the spinal cord.

In *Case* 16 (*Fig.* 424, *a* and *b*), although, as stated in the post-mortem notes, "the vertebral column was almost completely divided and the cord cut across," it is probable that the spine was not directly struck, but that the fractures were produced by the carrying away of the soft parts, this causing the tearing off of portions of the vertebræ and rotation of the whole spine. The wound was a large, deep laceration, running across the upper and middle dorsal regions. The right lung was lacerated. The body of the 3rd dorsal vertebra presented a complete vertical split through its centre, and this sagittal crack is associated with another one at the opposite pole of the vertebral ring, running through the right lamina, and thus dividing the whole bone into two almost equal halves. The vertebra above shows some tearing away of bone from the left transverse process and the under part of the spinous process, while the



FIG. 423.—*Case* 15. Cervico-dorsal spine. Very extensive bony damage.

vertebra beneath shows cracks in the right transverse process where the spine of the 3rd dorsal vertebra has impinged in the course of its violent rotation. It is noticeable that, although the extent of fissuring is here much less than in many of our cases, this is the only instance in which the continuity of the vertebral column was interrupted. The heavy lateral blow has produced rotation of a vertebra and tearing of the intervertebral discs, but is associated with comparatively little injury to the outlying processes, and with most severe crushing of the spinal cord; it thus recalls the effects of fracture-dislocation as ordinarily seen in civil practice, and the results have been produced by the same massive force exerted indirectly through the soft parts.



a *b*

FIG. 424 (*a*, *b*). —*Case* 16. (*a*) Vertical split of body of 3rd dorsal vertebra. (*b*) Is a reverse view, showing fairly extensive fissuring.

Case 17 (*Fig.* 425) shows an unusual form of injury to the spine, in which the contents of the vertebral canal were almost uninjured, but death was due to hæmorrhage from the vertebral artery. The patient was admitted with a wound of the left cheek, from which free oozing of blood was controlled by packing. He also complained of some



Fig. 425.—*Case* 17. Cervical spine. Metal *in situ*.

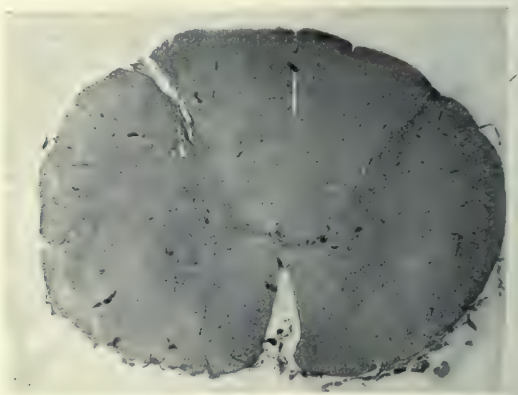


FIG. 426.—*Case* 17. Section of spinal cord with very localized hæmorrhage in left posterior cornu.

tingling in the left arm, but no other symptoms were noted. A week later there was sudden violent bleeding from the mouth, and death ensued in fifteen minutes. At the autopsy was found a metal fragment about the size of a large hazel-nut which, having perforated the lower jaw just in front of its angle and passed downwards and inwards through the root of the tongue, had come to rest in front of the 4th and 5th cervical vertebræ. The vertebral foramen of the 4th vertebra was laid open (see *Fig.* 425), and the transverse process cracked across. The 5th cervical showed a crack in front of the pedicle involving the body (seat of election), and cracks, without displacement, of both laminæ. The vertebral artery was ulcerated through at the level of the 4th cervical. The theca showed no abnormality, but in the spinal cord there was a minute hæmorrhage, smaller than a pin's head, occupying the left posterior horn (*Fig.* 426).

INJURIES TO THE THECA SPINALIS.

But little remains to be added to the remarks already made upon the condition of the spinal meninges in the above cases. It is throughout noticeable that, unless subject to direct impact of missiles or of bony fragments, the membranes are untorn even in cases in which the spinal cord is fatally injured—a condition quite analogous with what is found in the injuries of civil life. Tears in the theca, when present, show little or no tendency to retraction of their edges, and, just as in operations this membrane is most easily closed, so in injuries it seldom presents any large aperture. It is probably for this reason that the escape of cerebrospinal fluid from wounds is very rarely noted. Such escape often follows operations or accidental stabs and incised wounds ; but the swelling or displacement of parts in a gunshot wound appears to be quite sufficient to arrest it, the arrest being doubtless also due in part to adhesion of the membranes to the cord, a condition rarely if ever seen in aseptic injuries, but noticed in several of our cases. As is well known, the spinal dura mater, like that of the brain, is peculiarly resistant to infection from without, and meningitis was never met with except when there was gross perforation of the theca, and generally in the presence of a foreign body. Hæmorrhage around the theca is common, and in cases of late date we have several times found at operation a considerable amount of perithecal cicatrix, which appears to be capable of exercising pressure upon the subjacent cord. On the other hand, we have not met with any substantial hæmorrhage within the theca, although there can be little doubt that it occasionally occurs. No operations upon old-standing cases have shown adhesions between the cord and its membranes.

INJURIES OF THE SPINAL CORD.

We have already seen how seriously the cord may be injured even when the osseous lesion is of only slight degree or has been associated with immediate recoil of any displacement (*Cases* 1, 2, 7, 17, and 14), and the following are further examples of the same condition.

Case 18 was admitted with complete paraplegia due to a wound of the neck. An *x*-ray examination showed comminution of the 4th and 5th cervical arches on the right side, where a piece of metal lay outside the spine. Respiration was greatly embarrassed, and was failing rapidly on the third day, when operation was performed. The theca when exposed showed no signs of pressure, but presented a very slight scratch on the right side. Being otherwise quite normal, it was unopened. Death ensued from respiratory failure. The condition of the spinal cord is shown in *Figs.* 427, 428, and 429.

Case 19 was admitted with paraplegia due to a wound in the neck, "a foreign body having been removed from under the ligamentum nuchæ." The paraplegic symptoms, which were almost complete below the neck, persisted with but little change, except that some vague deep sensation was felt on the right side of the trunk and right thigh, while cystitis with pyrexia was directly threatening life. A skiagram showed no vertebral

injury. On the twenty-third day operation revealed merely some tearing and blood-staining of the interspinous ligament between the 4th and 5th cervical spines. Laminectomy, with exposure of two inches of the theca, showed no abnormality. Death occurred four days later from infection of the urinary tract, with multiple renal abscesses. At the post-mortem examination, the cord and membranes were quite normal to the naked eye, but on section the appearances shown in *Fig.* 430 were found.

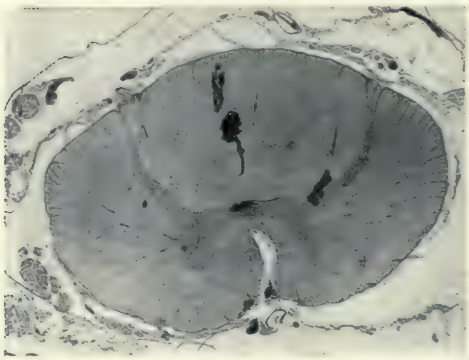


FIG. 427.—*Case* 18. Section of cord above area of necrosis, showing four large hæmorrhages.

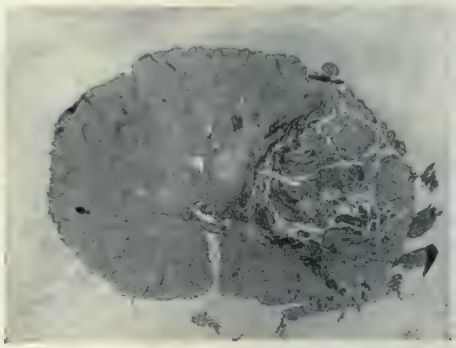


FIG. 428.—*Case* 18. Extensive area of hæmorrhagic necrosis

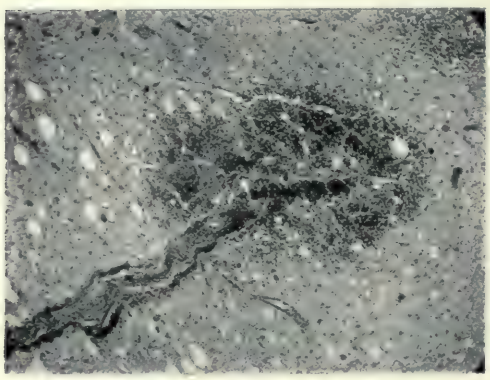


FIG. 429.—*Case* 18. Higher magnification of part of *Fig.* 427, to show a hæmorrhage.

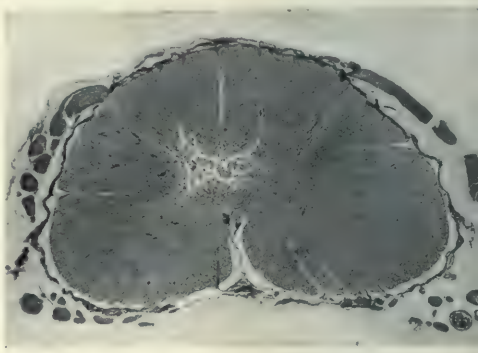


FIG. 430.—*Case* 19. Area of necrosis almost central.

Case 20, admitted with paraplegia below the mid-dorsal region ; died twenty-four hours later. The post-mortem examination showed that a fragment of shell had passed from left to right, abrading the spine of the 9th dorsal vertebra, not otherwise injuring the vertebral column, but coming to rest against the head of the 9th rib, which was fractured. There was some blood-clot around the theca at the level of the injury, and some congestion of its vessels. The uncut cord was normal to the naked eye, but on section revealed hæmorrhages and other changes similar to those found in the previous case (*Figs.* 431, 432).

In cases of this type, which are often spoken of vaguely as cases of concussion of the spinal cord, the bruising and hæmorrhage is clearly not always due to osseous displacement, whether with or without recoil, and must have more often resulted from the general disruptive or divulsive wave which is characteristic of gunshot injuries in all regions. The appearances are, however, very uniform, and closely similar to those produced by direct crushing of the spinal cord.

Serial sections show to the naked eye a spindle-shaped area of petechial hæmorrhage with necrosis, extending throughout two or three segments of the cord, most marked at the point of impact or of the divulsive wave, and thence tapering off both upwards and

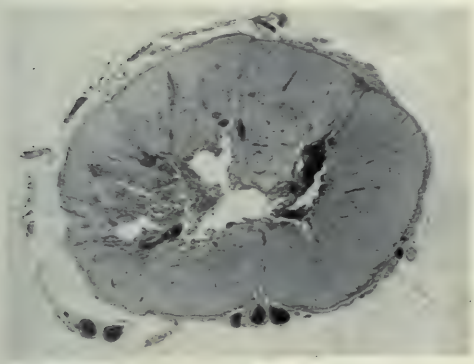


FIG. 431.—*Case* 20. Numerous hæmorrhages and extensive necrosis.

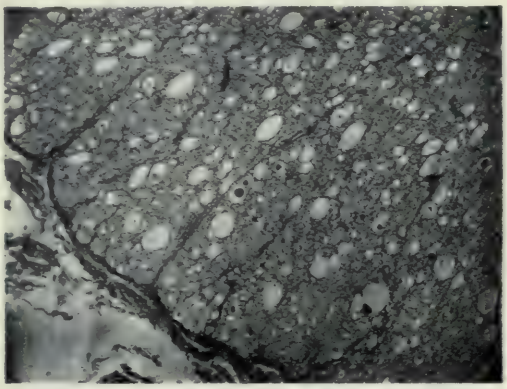


FIG. 432.—*Case* 20. Portion of lateral column seen in *Fig.* 431, highly magnified to show sieve-like structure of the white matter and some swollen axis cylinders.

downwards, the upward prolongation being as a rule longer and more tapering. We thus have two cones of destruction, united at their bases, and the lower generally much more truncated than the upper. In the whole of this area the destruction tends to be more marked in the central grey matter than in the firmer and less vascular lateral fibres. The medullary substance is completely disintegrated, and intermingled with it are numerous small areas of extravasated red blood-corpuscles. Around this hæmorrhagic area is a certain amount of œdema, affecting especially the axis cylinders (*Fig.* 432), and associated with Nissl degeneration of the anterior cornual cells. Intra-radicular hæmorrhages were also occasionally found. We were unable to detect any evidences of reparative changes, even in such an instance as *Case* 19 (*Fig.* 430), where the patient survived the injury twenty-seven days.

It will be obvious that the changes here described, and resulting from impact of minute fragments of bone or of the disruptive wave of a gunshot injury, are all of the nature of contusions of the spinal cord ; and that although they are sometimes spoken of as 'concussion,' they have little or nothing in common with the lesions which may be produced by heavy falls and blows, or by proximity to explosions, in which we have a generalized rather than a localized effect. We have seen numerous cases in which gunshot injury of the back is accompanied by more or less complete paraplegia which tends to recovery, but we have no pathological evidence as to the changes produced in such cases. We can only surmise, without being able to prove, that they also are due to minute hæmorrhages resulting from the divulsive wave. The nearest approach to confirmation of this view is furnished by *Case* 17, in which the sole nervous symptom was 'numbness' of the left arm, and the sole pathological appearance a small hæmorrhage in the left posterior root. Had this patient not died from other causes, it would have been impossible to prove the existence of this minute injury.

RESTORATION OF THE URETHRA BY MEANS OF BAER'S MEMBRANE.

By Captain JOSEPH E. ADAMS, R.A.M.C.T.

The following case of gunshot wound of the urethra is of interest, by reason of the ease with which a distressing condition has been relieved, and the degree of success which has attended the operation. It is true that there will be some permanent stricture along the course of the urethra ; but this is certainly preferable to the degradation, to the male mind, of micturition via the perineum, and it can be controlled by the regular use of sounds.

Private S., age 22, was wounded Nov. 27, 1917, by a fragment of shell which entered through the perineum and emerged above the pubes at the root of the penis. There was a large ragged wound between the legs, involving the scrotum, but the wound of exit was small. Healing took place slowly, and both wounds were not closed until February, 1918. The testicles were not damaged, there was no bony injury, and the bladder was not involved in the wound.

When I examined him in April, the penis was shortened, and approximated to the abdomen by a recently healed cicatrix over the pubes. All his urine was voided through a fistulous opening behind the scrotum, and a catheter could easily be passed through this into the bladder. A sound could be passed about one inch down the urethra from the urinary meatus, but no further. It was therefore clear that the urethra between these points was seriously damaged, if not destroyed. It seemed rather improbable that it could be restored by operation ; and my own experience of operations for hypospadias, either by simple plastic operation, or by vein-grafting from the internal saphenous, had been so unsatisfactory that I made no promise to the patient except that I would endeavour to restore the urethral channel. He was quite ready to accept the risk of failure, and is consequently more than delighted with the success of the operation.

Operation, April 22.—The lithotomy position was used. A director was passed from the perineal fistula into the bladder, and a sound from the urinary meatus to the scar tissue in the body of the penis. The scrotum was next split down to the proper level of the urethra, of which practically no trace could be found. Scar tissue was removed, the two ends of the urethra were dissected free for about half an inch, and the edges were freshened for the application of the sutures to hold the new urethra of Baer's membrane.

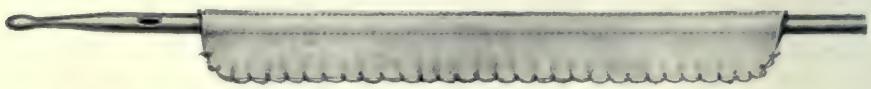


Fig. 433.—Artificial urethra, constructed by sewing a piece of Baer's membrane round a catheter.

This was next constructed by sewing a piece of membrane* round a No. 9 English gum-elastic catheter—very loosely in order to allow of subsequent contraction—as shown in *Fig.* 433. The total length of the gap in the urethra was five inches, and the artificial one was therefore made about three-quarters of an inch longer, so that it might be invaginated for a short distance into the urethral ends and fill the gap without tension.

* The Baer's membrane used in this case was that prepared by Johnson and Johnson, of New Jersey. It is described by the makers as 'chromatized medium-hard,' and prepared in accordance with the suggestions of Dr. Wm. Stevenson Baer. After removal from its sterilized envelope it was merely soaked in sterile normal salt solution for five minutes before use.

I am indebted to the theatre sister for the care with which this membrane was sutured around the catheter, and it should be noted that it was designed to be of nearly three times the actual diameter of the catheter, except at its ends, where it fitted more closely. Its edges were approximated by a single running iodized catgut button-hole suture.

The artificial urethra was next put in position by passing the catheter from the meatus into the gap, through the membranous tube, and then through the posterior opening of the urethra into the bladder. Care was taken to apply the sutured edge of the tube to the deep aspect of the wound, i.e., towards the dorsum of the penis, since it was thought that this would tend to prevent leakage ; the ends were invaginated into the two open mouths of the urethra, and were secured here by several catgut stitches, which in places penetrated the membrane owing to its thinness.

The next step consisted in dissecting up a flap of soft tissue from each side of the floor of the wound rather greater than the length of the urethral gap, both from penile and scrotal tissue, as is done in plastic operations for hypospadias ; interrupted catgut was used to secure this second channel over the artificial urethra so that its suture line lay over the unbroken surface of Baer's membrane. Hæmostasis being secured, the skin was closed with interrupted sutures of salmon-gut, leaving two small rubber drains at the anterior and posterior limits of the wound. In order to avoid risks of leakage of urine during the healing process, the bladder was next filled by means of the catheter already *in situ*, and suprapubic drainage by a Guyon's tube carried out. The catheter was then fixed in position by adhesive strapping, and sutures passing through the prepuce.

Post-Operative Course.—All the urine drained by the suprapubic route for the first eleven days. The rubber drainage tubes were removed on the fourth day, and the wound healed by first intention, except at two points close to the ends of the true urethra. At both these points there was slight leakage of urine,—enough to demand daily dressing for a few days—but the posterior sinus healed about a fortnight after operation. The Guyon's tube was removed on the twelfth day, and the urine then drained away by the catheter, to which a long rubber tube was attached. A small slough was removed from the anterior sinus on the fifteenth day, and the catheter was finally taken out eighteen days after operation. It came out with perfect ease, and there was no sign of its being gripped at any point by scar tissue. The urine remained normal throughout. There was a small slough about $\frac{3}{4}$ in. in length around the catheter close to its bladder end, and I think this represented a very small portion of the Baer's membrane. Normal micturition followed the removal of the catheter, but the anterior sinus leaked for several weeks. To aid the closure of this, a No. 6 silver catheter was passed under anæsthesia and tied in for four days, the edges of the fistula being freshened and approximated with a couple of catgut sutures. Six weeks after the first operation the patient was again examined under an anæsthetic, and a 20–24 Clutton's sound was passed easily. Urethroscopy revealed no definite stricture at any part of the urethral canal, but the walls were abnormally vascular, though quite smooth. Two days later the fistula was healed, but it has broken down once or twice since, after larger sounds have been passed. On Nov. 4 a 26–30 Clutton's sound was passed under chloroform anæsthesia, and since that date sounds have been passed at regular intervals without the aid of an anæsthetic. The patient is now (December, 1918) able to pass size 18–22 himself. As soon as he is able to pass a 20–24, I propose to provide him with his own sound, and he will be ready for discharge, provided he promises to pass the instrument regularly at short intervals. He has already shown that he understands the principles of asepsis.

My own experience of the simple plastic operation commonly recommended for the treatment of mild cases of hypospadias has been disappointing, and in selecting Baer's membrane to protect the suture line, I was influenced by the statements concerning its value in arthroplasty, where it is said to undergo organization into tissue corresponding to that which it replaces.

I considered the advisability of utilizing a tube of his own fascia lata, or the internal saphenous. I decided against the latter because I am convinced that it is essential to

provide a wide channel, and I have found that an excised vein, when emptied of its blood, becomes a very narrow tube. Baer's membrane probably possesses an advantage over fascia in that it is already 'shrunk': though I must confess that hitherto I have favoured the use of autogenous rather than heterogenous grafts in arthroplasty and similar operations.

I feel sure that success in such cases depends on providing at least two layers of tissue to resist leakage of urine, and also on drainage of the bladder above the pubes for a considerable time. It was rather surprising to find that, with the Guyon's tube and catheter both in the bladder, all the urine drained by the suprapubic route and none came through the urethral catheter. Within three days of the removal of the suprapubic tube this opening had closed and all urine was voided by the catheter. I shall certainly adopt more careful precautions against leakage of urine in operations for congenital deformities of the penis and urethra in future, and it seems important to insist on suprapubic drainage as an essential step towards success in these operations. The restlessness of a child patient must certainly be guarded against, as it is easy to dislodge these tubes.

I should like to conclude this short article with a tribute to the wounded British soldier, who is the best type of surgical patient I have ever had to deal with.

My thanks are due to Colonel H. P. Hawkins, commanding the 5th London General Hospital, for his permission to publish this case.

THE TREATMENT OF FUNCTIONAL DISABILITY OF THE LIMBS IN A SPECIAL MILITARY SURGICAL HOSPITAL.

By Lieutenant WM. CUTHBERT MORTON, C.B.E., R.A.M.C.

Officer in charge of the Re-education Department of the 2nd Northern General Hospital, Leeds.

FOREWORD.

The functional hospital is a paradise in which, as Antonio would say, the healer is "a spirit of persuasion" and the patients "take suggestion as a cat laps milk." The special surgical hospital, on the other hand, is a combined purgatory and inferno in which the functional healer is kept humble by the slow and imperfect results of his treatment and only too often is tormented by its absolute futility. In the functional hospital it may be possible to cure in the first sitting a score or two of consecutive cases, but in the special surgical hospital he would be fortunate indeed who should cure five which were not deliberately selected.

In March, 1917, the writer was appointed to take charge of the massage department of the 2nd Northern General Hospital, and it was not long before he became convinced that massage and electricity were of little or no benefit—and indeed on occasion were positively harmful—in certain cases which should nevertheless be cured or at least improved by intensive training. Thus, a man who had been in the hospital for four months was still closing his hand by extension of the first and flexion of the second and third phalanges; yet a simple demonstration of the muscular mechanism of the disability brought about closure by full flexion within forty minutes; and although at first the movement was cautious and slow, he soon regained complete control. Again, a man who had for some time been trained elsewhere by one of the best of our masseuses was, after twenty months of hospital life, still going about on crutches with a knee rigidly extended and a profoundly flaccid foot; yet after fifteen minutes' training he was able to walk perfectly without support.

After a few months in the massage department, the writer was asked by Lieutenant-Colonel Littlewood, Officer Commanding the 2nd Northern General Hospital, to undertake the training of five or six cases for a few weeks in order to see what could be done along these lines; and out of this small beginning grew the re-education department of the 2nd Northern General Hospital. Although from the outset the importance of this kind of work has been recognized, and much interest has been taken in the department by the authorities, yet the demands on the hospital have been so great that it has never been found possible either to house or to staff the department adequately.

At first the patients were grouped together in a ward (which was, however, shared with a surgeon), and out of the few cases of general 'shell shock' which we then had, several did very well indeed; but partly, perhaps, because we had not yet gained sufficient confidence in the methods of treatment which we were then only evolving, chiefly no doubt because of the large proportion of cases in which the training was hampered and prolonged by organic trouble, it was impossible to create an 'atmosphere,' and the men were once more scattered among the surgical cases throughout the hospital, attending the re-education department as out-patients. In a functional hospital the atmosphere appears to be everything; but in a special surgical hospital it is out of place for all cases in which organic and functional disabilities are closely interwoven, although it may be desirable for those whose disability has become purely functional. The procedure now adopted is as follows.

Admission into Hospital.—Patient is admitted into and retained in one of the surgical wards under the surgeon's care, except that some of the pensioners are treated throughout as out-patients.

Reference to the Re-education Department.—After the surgeon has completed his examination, he refers the patient to the re-education department if he thinks that part of the disability may not be organic. All cases so referred are welcomed, since at times treatment is the only means of deciding how much is purely functional, and even if the case is purely organic something can always be learned from it. Each patient is examined for the first time privately, and no one is ever treated in such a way as to lead him to think that his disability is not regarded as a very real thing. It is quite possible to conduct the examination without giving rise to any unfortunate 'suggestion.'

Complaint and Previous History.—Patient explains what he cannot do, and is then asked about anything previous or subsequent to the disability which may have any bearing on the case—as, for example, whether he has had the trouble before, or suffered from paralysis as a child, whether foreign bodies have been removed or are still present, and so on.

Appearance of the Limb when Patient is at Rest.—The limb is examined for œdema, scars, deformities, abnormal postures, involuntary movements, and the like.

Disability in Voluntary Movement.—The movements which the patient cannot voluntarily execute in a perfectly normal manner are noted. The whole limb should be examined in every case, since in drop-foot, for example, the leg and thigh may also be involved so that weakness of abduction at the hip-joint may have caused the pelvis to drop on the other side.

The Muscles Involved in the Disability, and their Condition.—The muscles which are not functioning properly are noted, with special reference to their condition both when the patient is at rest and also when he is attempting voluntary movement. They may be normal, or flaccid, or in spasm (tonic, clonic, or irregular), or they may be simply inco-ordinate. Muscles are good servants, but bad masters. When voluntary control is lost, "the state of a man, like to a little kingdom, suffers then the nature of an insurrection."

The writer is inclined to think that too much attention is focused upon the voluntary contraction and relaxation of the muscles, insufficient emphasis being laid on the fact that when the will is inactive the muscles live a life of their own, influenced chiefly by reflex impulses, but partly also by the composition of the blood which is circulating—it may be very sluggishly—within them. It is impossible to believe that every functional disability has been brought on by suggestion; and the man who persists in a functional disability initiated by organic mischief may be no more of a hysteric or a malingerer than the man who remains deaf for some time in the belief that he is incurable, although, when he is at last persuaded to have medical advice, he recovers his hearing completely as soon as the ears are syringed; it was a mistake, stupid perhaps, but no more.

The Cause of the Condition.—The first problem is diagnosis. How much of the trouble is organic? Is there, or has there ever been, any direct damage to the muscles themselves, to the bones upon which they are designed to act, or to the upper or lower motor neurones by which they should be controlled? Or is it that the tone of the whole muscular system has been so lowered that those muscles which in the course of evolution have been subjected to the greatest strain (as, for example, the peronei, or the abductors of the hip, or the deltoid) can no longer 'carry on'? Or is there indirect organic trouble? Is there a reflex (painful or simply protective) causing spasm, or is œdema hampering the muscles (partly by faulty nutrition and removal of by-products, partly by thickening and stiffening of the limb and of the muscles themselves)? Or have the muscles been so long out of action that their sensory mechanism is out of gear? Is their any alteration in the equilibrium of the body, such as a short limb causing pelvic drop and scoliosis, or on the other hand an injury causing scoliosis followed by pelvic uptilt and an apparent shortening of the limb? Is there a loss of the normal muscular antagonism, through a direct injury of the antagonists or their nerves?

Many cases require several sittings before they can even be diagnosed, and in some the diagnosis can never be certain. Every case should be reviewed from time to time, and frequent consultation between re-educator and surgeon may be necessary, as well as

one or more radiographs or neurological examinations. No case in which there is any doubt—indeed, it might almost be said, no case whatever—should be treated as functional without full examination. The following cases among others show how closely the organic and the functional may be intertwined. Flaccidity of the lower limb has been complicated by synovitis of the knee, rupture of the ligamentum patellæ, incurable stretching of the tendon of the rectus muscle, and Hey's internal derangement of the knee-joint. In one case the pelvis was dropped because of irreparable damage to the abductors of the hip: in another it was uptilted owing to a similar condition of the muscles of the abdominal wall. A flaccidity of the deltoid, diagnosed as obviously functional, was due to a subdeltoid periostitis. Imperfect closure of the fingers sometimes depends upon an organic injury to one or more phalanges or joints of a single finger, especially the medius. In one case a functional flaccidity of the whole upper limb was complicated during treatment by the development of an organic paralysis of the musculocutaneous nerve due to constriction by scar tissue along the track of a foreign body. Finally, in one of the surgical wards, a man who limped slightly, though he declared that he had never been wounded, was found to be suffering from Brown-Séquard's paralysis caused by a bullet embedded in the spinal column.

Treatment.—In every case a plain statement of the facts and difficulties is made to the patient. If any part of the disability is incurable, he is frankly told so. The rest of the trouble is explained as being due to muscle habit, and curable: and as far as possible some period is fixed within which he should be quite cured, whether it be one lesson, one day, one week, or one or more months, due emphasis being laid on the fact that, as in all physical training, a great deal depends upon his own efforts. It is gratifying to note how interested most of these men become in their training, and how it fosters their self-respect. Equally noteworthy has been the enthusiasm of all the trainers who have been working against such odds during the last eighteen months. Diagnosis is the duty of the medical officer, but most of the actual training is carried out by sisters and V.A.D.'s, in whose hands the cases can as a rule be safely left when once the diagnosis has been determined and the form of treatment settled.

Although the methods of treatment vary according to the nature and site of the disability, yet they are all based upon the same principles—namely, stimulating the muscular sense, restoring the reciprocal action of antagonists, and co-ordinating all the muscles under the unerring control of an educated central nervous system. It is impossible here to enumerate the different clinical types and the details of treatment. Notes are, however, appended of a few cases specially selected as illustrating the work of the department from various points of view. Cases could easily have been chosen in which the results might have appeared more striking; and others still more easily which were, or might have appeared to be, failures.

ILLUSTRATIVE CASES.

I. UPPER LIMB.

Case 1.—**Closing of the hand by extension of the first and flexion of the second and third phalanges, following a gunshot wound of the arm.** (*Figs.* 434 *A–E*).

Pte. R. M., age 22, received a gunshot wound in the left arm on Feb. 27, 1917, and was admitted to the 2nd Northern General Hospital on June 21.

Re-education Department.

June 22.—Left upper limb is in no way paralyzed. On being told to close the fist, he extends the first phalanges fully and fully flexes the second and third, the whole hand being then kept rigid (*Fig.* 434 *A*). Once the movement has begun, it is not possible to flex the first phalanges passively. The condition is due to immediate over-action of the extensors. On being shown how to keep his hand absolutely relaxed, and then to flex gently the first, the second, and lastly the third phalanges, he carries out the movement perfectly, though very slowly. The two conditions of the hand can be reproduced at will by strong and sudden, or on the other hand by slow and gentle, contraction.

June 29.—Improving slightly.

July 6.—Can flex correctly much more rapidly than before, but very sudden flexion reproduces the disability. Grip exercises.

July 13.—Improving.

July 18.—Greatly improved. He can close his fist more rapidly than even last week. Also, even when he does it very rapidly, and therefore incorrectly, the carpo-metacarpal joints are much more flexed than before.

July 30.—Almost right.

Aug. 1.—Cured.

This case, interesting in itself, is to the writer particularly so, since it was the very first which he cured. The faulty closure was apparently a simple muscular inco-ordination. There was no paralysis, and so long as the hand was at rest, there was no spasm. When, however, patient attempted to close the hand, which he always did with considerable vigour, the interossei did not act strongly enough to flex the first phalanges, so that when the sublimis and profundus flexed the second and third phalanges, their forcible contraction, in the absence of the flexion of the first, brought into play the strong counter-pull of the extensors which is normally seen under corresponding conditions. The flexors pulled harder and harder, but this was countered by the extensors, and as each group called in more and more muscles to assist it, the whole limb at last became rigid, even the trunk being bent over to that side in the desperate attempt to close the hand. Treatment consisted (1) in explaining to the patient the mechanism of the disability; (2) in making him relax every muscle of the limb; and (3) in training him in successive flexion—that is to say, to extend his fingers, and then in the gentlest possible manner, and if necessary with the help of passive movement, to flex in succession the first, second, and third phalanges (*Figs.* 434 *B*, *C*, *D*, *E*). In this way the interossei are brought into play from the first, the contraction of the sublimis and profundus is kept within bounds, and the extensors are never unduly stimulated. When once the hand could be perfectly closed in this gentle fashion, daily practice soon increased the speed and power of the flexion. The notes show well the gradual progress of the case. In some cases it will be found that although perfect range of movement is soon recovered, the power of the grip is very slow in returning; and this is often seen with other types of disability of the hand.



FIG. 434.—(*A*) Closure of the hand by extension of the first and flexion of the second and third phalanges, as in *Cases* 1 and 2. (*B*), (*C*), (*D*), (*E*), Positions of the hand in successive flexion.

Case 2.—**Closing of the hand by extension of the first and flexion of the second and third phalanges, following a gunshot wound of the shoulder with injury to all the cords of the brachial plexus** (see *Fig.* 434).

Cpl. A. M., age 21, was shot in the shoulder on Sept. 14, 1916, and was admitted to the 2nd Northern General Hospital on July 3, 1917.

Surgical Ward.

July 3.—Shrapnel bullets entered below outer half of right clavicle, passed downwards and outwards, and emerged about lower angle of scapula. Upper arm apparently normal. Shoulder normal. Forearm: wasting of flexors. Ulnar palsy in hand.

July 6 (*Nerve Report*).—Severe lesion of all cords of brachial plexus, worst of inner cord. Former anæsthesia now gone. Ulnar distribution only 'numb' now. All muscles respond to faradism except those of posterior cord (which are powerful in voluntary effort).

Sept. 6 (*Nerve Report*).—Little change yet.

Nov. 14 (*Nerve Report*).—All muscles respond to faradism. Slight sensory loss, ulnar area only.

Re-education Department.

Dec. 18.—A typical case of disability in closing the hand by extension of the first and flexion of the second and third phalanges. Abduction and adduction of the fingers is not possible. This is to some extent due to the hyperextension of the first with flexion of the second and third phalanges which is the result of the organic lesion and is now probably incurable. With re-education he will rapidly recover considerable range of voluntary movement.

Dec. 20.—Closes his hand perfectly well now. Cannot yet extend his third, fourth, and fifth digits properly. This is due to the hyperextension of the first phalanges and shortening of the extensors causing tension on the long flexor tendons. For this, re-education will do no good.

Dec. 31.—Disability in flexion cured. For the rest, work and time will do as much as any treatment.

This case shows how an inco-ordination may be the result of the orderly recovery of an organic nerve lesion, a result which persists after the lesion itself has recovered, simply because the man does not know that he can be cured, still less that he can cure himself. The bullet injured all the cords of the brachial plexus, and especially the inner cord, so that the nerve-supply to the muscles of the fingers was interfered with, and especially that to the flexors. The order of recovery would thus be—first the extensors, then the long flexors, and lastly the interossei. Now, when a part is disabled, the effort to overcome the disability commonly results in all the muscles of that part, and sometimes those of other parts also, being simultaneously called into action, even although their action is to antagonize one another. When, therefore, in this case the flexors began to recover, the effort to flex brought into play the more powerful extensors; and since these were acting chiefly on the first phalanges, while the interossei were not yet able to extend the second and third, the effort at flexion resulted in a faulty closure of the hand by extension of the first with flexion of the second and third phalanges. When at last the interossei gradually recovered, they had to give way before the long flexors, which were themselves overpowered by the extensors. This inco-ordination was therefore in its onset organic, and it persisted through sheer force of habit, since the man failed to realize that he could close his hand perfectly if only he would set about it in the right way. No doubt he responded to the strong suggestion afforded by the severity of the injury which had originally disabled him; but there is no need to suppose that he was either malingering or hysterical.

Case 3.—**Limitation in flexing the fingers owing to organic disability of the middle finger.** (*Figs.* 435 *A–G.*)

Pte. F. E., age 26, was wounded by a bullet in the left hand on April 13, 1917, and was admitted to the 2nd Northern General Hospital on Oct. 15.

Surgical Ward.

Oct. 17.—Compound fracture of left middle finger which is entirely healed. Last phalanx bent to radial side. Finger extended and unable to flex. Other joints of hand movable.

Nov. 16.—Last joint of left middle finger excised to straighten distal phalanx.

Re-education Department.

Jan. 4, 1918.—The second and third phalanges are out of court, and the whole finger is useless. Not only so, but this is apparently the cause of the disability of the index, ring, and little fingers. Compare the other hand (*Fig.* 435 *A*). Amputation of the whole medius might restore the use of the rest of the hand.

Jan. 10.—The finger can be fairly well relaxed by patient, and completely flexed by passive movement.

Feb. 28.—The flexor digitorum profundus as a whole is working very badly. Patient is unable to bend the terminal phalanx of any finger well.

March 7.—Would suggest disposal, as no further improvement is noted and no operative measure is wanted by the patient.



FIG. 435 *A*. — The normal hand in *Case* 3. Voluntary extension of the middle finger, with imperfect flexion of the third phalanges of the other fingers. Note the convergence of the index and ring fingers.



FIG. 435 *B*.—Organic stiffness of the middle finger, with imperfect flexion of the terminal phalanges of the other fingers.

In this case there was: (1) A primary organic disability of the middle finger; (2) A secondary organic disability of the other fingers; and (3) A functional flaccidity of the profundus.



FIG. 435*C*.—The same case some months later.



FIG. 435*D*.— Side view of a similar case.

1. The inability to flex the middle finger was organic, being due to the wound.

2. The inability to flex the other fingers (chiefly the terminal phalanges) was also organic, being the inevitable result of the inability to flex the middle finger. At first

sight it might appear that the inability to flex completely the index, ring, and little fingers was due to a purely functional flaccidity of the profundus. A very similar condition was, however, found in the sound hand, in which, if the middle finger was kept either actively or passively extended, the terminal phalanges could not be flexed (*Fig.* 435 *A*) This is quite often seen in normal hands; and if the attempt to flex the fingers be both sudden and vigorous, there may be acute pain at a greater or less distance above the wrist, apparently because the belly of the profundus to the middle finger either contracts and cannot shorten, or else is stretched by the contraction of the bellies to the other fingers. In the case described above, the tips of the index and ring fingers converged; but this, too, is seen in many normal hands, being indeed to some extent found on the sound side in this very case. In certain cases, if the individual fingers be flexed by the sublimis in the order little, ring, middle, and index, each finger will overlap its predecessor, and will only fall into position by sliding down its side.

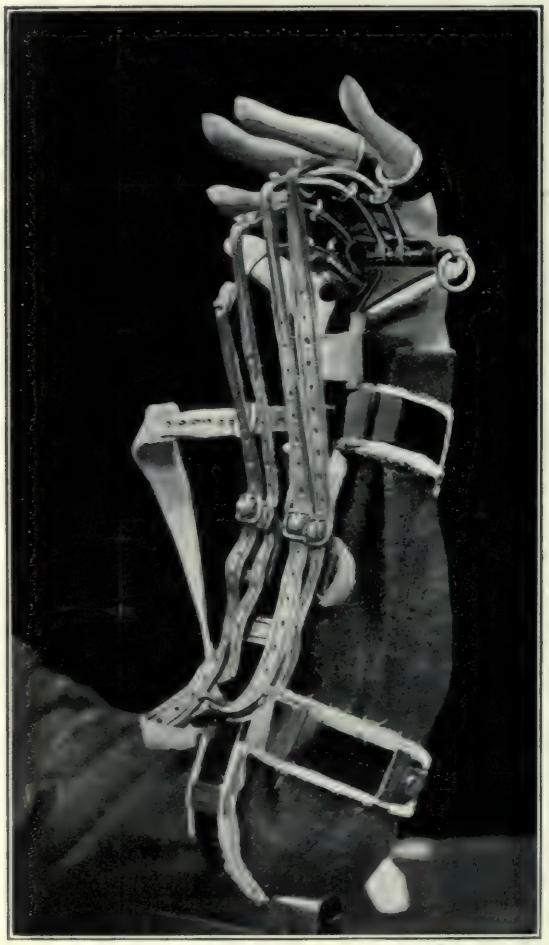


FIG. 435*E*.— Metacarpo-phalangeal flexion splint.

3. There was also a purely functional flaccidity of the profundus, best seen when the patient tried to flex the third phalanges while the first and second were held in passive extension. The main duty of the profundus is to co-operate with the sublimis in securing complete closure of the hand. Since the muscle could not be used for this purpose, it is scarcely surprising that it should have become flaccid. Unless the organic disability of the middle finger could be eliminated, the whole profundus, even were it cured, would almost certainly relapse; and in any case the cure would be of little value, since the muscle could only come into play in a movement of no importance. The choice lay between amputation of the middle finger, and division of the tendon of the profundus to the middle finger; but surgical measures were refused.

There have been other cases with a somewhat similar disability (*Figs.* 435 *B*, *C*, *D*), and one (*Fig.* 435 *F*) in which the other fingers could be fully flexed although the medius remained fully extended. In this last case the joints of the middle finger were perfectly supple, but there was no voluntary power of flexion, nor could the finger be flexed by faradism. As there was a deep scar in the palm at the base of the finger, the flexor tendons had evidently been severed. The other bellies of the profundus would thus be free to flex the terminal phalanges of the other fingers.

Organic stiffness of the metacarpo-phalangeal joint of one or more fingers seriously hampers re-education of the hand. In order to overcome it, the writer has devised the



FIG. 435*F*.—Loss of flexion of the middle finger (which is, however, quite supple) with perfect flexion of the third phalanges of the other fingers. The flexor tendons had been severed by a wound at the base of the middle finger, so that the remaining tendons of the profundus were unhampered.



FIG. 435*G*.– Functional lagging of the middle finger, which had been injured about six years previously. Closure of the hand was perfect after one lesson.

splint shown in *Fig.* 435 *E*, which will fit a large or a small limb, whether right or left, and can be applied to one or more fingers, each being dealt with independently so as to secure its maximum flexion.

Case 4.—**Overaction of the flexors in extending the wrist after recovery of a lesion of the musculospiral nerve.**

Pte. F. C., age 32, was referred to the re-education department of the 2nd Northern General Hospital on Sept. 11, 1917, unable to extend the left wrist properly after recovery of a lesion of the musculospiral nerve.

Re-education Department.

Sept. 11.—Muscular resistance to extension of wrist. Re-education soon gives good result.

Oct. 9.—Movements apparently perfect, but patient complains of pain on lifting anything heavy.

This case has four points of interest : (1) The preponderance of the flexors is merely the continuance of what was for months an organic inco-ordination. (2) Even when function was restored, patient complained of pain on lifting anything heavy. Pain often vanishes in a surprising way when the part is once more functioning properly ; but often



Fig. 436.—Long skeleton cock-up sling-splint (see note to *Case* 5).

it remains, and one must always be careful in diagnosing any pain as purely functional, since the subsequent course of the case often reveals the presence of definite organic trouble. (3) Although this case did well, there are some of this type which are difficult to cure, possibly because the shortening of the muscles has become complicated by fibrous changes. (4) In such a case as this a long skeleton cock-up sling-splint is often useful (*Fig.* 436, and see comment on *Case* 5).

Case 5.—**Over-action of the flexors of the wrist and of the long flexors and extensors of the fingers, with weakness of the interossei, following a gunshot wound of the forearm (*Figs.* 437 *A*, *B*).**

Pte. A. M., was wounded through the left forearm on Oct. 14, 1917. He was admitted to the 2nd Northern General Hospital on April 26, 1918.

Surgical Ward.

Through-and-through bullet wound of middle of left forearm. Hand held in claw position, deviated to ulnar side, and pronated. Considerable atrophy of hypothenar group of muscles. Wrist dropped, spastic contraction of extensors of hand. Very limited power in flexor profundus, practically none in sublimis, very slight power in thenar group, none in intrinsic muscles of hand.



Fig. 437*A*.—Overaction of the flexors of the wrist and of the long flexors and extensors of the fingers, with weakness of the interossei, following a gunshot wound of the forearm (*Case* 5).



Fig. 437*B*.—The same case after training.

Very slight power of pronation and supination. Blunting of sensation in ulnar, median, and posterior interosseous distribution. Passive movement possible at wrist-joint, no voluntary power.

May 16 (*Nerve Report*).—Mainly if not wholly functional. Spasm passed off to a great extent when the muscles were tired by action.

Re-education Department.

May 24.—Position of rest: Three-quarters pronation, drop-wrist, hyperextension of first phalanges, marked flexion (45°) of second, and slight flexion (0°–10°) of third (*Fig.* 437 *A*). Great rigidity, but absolute relaxation can be obtained.

Aug. 2.—Has never been to the department since May 24. Hand now as it was then. Position of rest the same. Rigidity the same. Relaxation as before.

Sept. 16.—Less muscular spasm.

Oct. 16.—Has now good voluntary movements in every way, though the hand in repose resumes the old position. Time and use should now do as much as further treatment.

This deformity corresponds in some ways to that in the foot known as pes cavus. The extensors and long flexors are in spasm, whereas the interossei are either overpowered or not acting at all. The treatment consisted in absolute relaxation, successive flexion, and the like. The patient was discharged before the muscles had quite resumed the normal co-ordination of rest. Perhaps he ought rather to have been given a long leave, say two months. In the later stages of the cure these cases often do extremely well if sent home for some weeks, especially if they can find any appropriate work. Many a case which is dragging rather wearily to its close is satisfactorily cured in this way, provided the man can be trusted to persevere in training himself at home.

For this and similar cases—especially where, as in *Case* 4, there has been a lesion of the musculospiral nerve—the writer has devised the skeleton sling-splint, one form of which is shown in *Fig.* 436. The hand must not be immobilized, nor yet must it hang down at the patient's side. This splint therefore dispenses with all bandages, and acts as a sling for the forearm, while at the same time the wrist is kept extended by gravity. If the cross-straps are undone, the limb can be freely used ; and yet whenever it comes to rest, the proper position is ensured. When the metacarpo-phalangeal joints should be allowed to flex, a short skeleton sling-splint should be used. The metal band which runs half-way up to the left shoulder stabilizes the splint.

Case 6.—**Over-action of the extensors and flexors of the wrist and of the extensors and long flexors of the fingers, with weakness of the interossei, following a lesion of the ulnar nerve** (*Figs.* 438 *A*, *B*).

Pte. F. B., age 26, was wounded in the left wrist on Sept. 16, 1916, and admitted to the 2nd Northern General Hospital on April 26, 1918.

Surgical Ward.

April 26.—Through-and-through bullet wound of wrist. Wound of entrance just below styloid process of ulna, dorsum of wrist ; exit at lower end of ulna, palmar surface. Hand held in claw position, contraction of extensors. Can be passively extended ; voluntary power practically nil. Atrophy of muscles of dorsum of hand. No voluntary movements of fingers or thumb. Considerable blunting of sensation in ulnar and median areas.

June 3 (*Ner e Report*).—Partial ulnar lesion, and very slight sensory loss in median area. Ulnar muscles of hand are powerless, but react to faradism, with exception of outer interossei. Median muscles have power, and react to faradism. Ulnar sensory loss incomplete ; no deep loss. Considerable contraction of extensor group.

July 10 (*Nerve Report*).—Improvement in ulnar lesion. Less absolute sensory loss. Contracted extensors cause most disability, and the trouble is largely functional.

Re-education Department.

July 12.—Some organic rigidity of the wrist. On waiting list.

July 25.—Does surgeon think the extensor tendons should be lengthened ?

Aug. 12.—Tenotomy of extensor tendon to middle finger.

Sept. 20.—The condition resembles pes cavus, but the wrist is organically stiff, so that it cannot be much flexed. The spasm of the extensors and flexors may be a reflex irritative condition. Should like to try re-education for one month if surgeon approves. Tenotomy has done no good.

Oct. 5.—Not a great deal of spasm now in the long extensors of the fingers, and very little in the sublimis and profundus. Should be inclined to recommend freeing ulnar nerve from scar above wrist in the hope of helping the action of the interossei.

Oct. 16 (*Nerve Report*).—The slight organic lesion of the ulnar may be at the bottom of the functional disturbance ; careful neurolysis might help.

Surgical Ward.

Oct. 21 (*Surgeon's Report*).—Operation, ether. Ulnar nerve exposed at wrist. Considerable scar tissue. A small bulb of nerve, which was not very hard. Nerve freed from scar tissue.

Re-education Department.

Nov. 23.—In hand again. No change.

Nov. 30.—Interossei still respond badly to faradism.

Dec. 14.—Improving.

Jan. 4, 1919.—Much improved.

Jan. 23.—Wrist : Voluntary extension full, also flexion until organically limited. Fingers : With wrist extended, index and medius can be fully extended, ring not quite, little finger less ; with wrist in axis, ditto. Action of interossei : Index and medius flexed 90°—0°—0°, ring and little finger, 45°—90°—45°. This condition had a very definite organic basis. The interference with the ulnar nerve is now passing off. Should recommend two months' leave.

How much of this disability was organic, and how much functional? There can be little doubt that there was a distinct lesion of the ulnar nerve, upon which the non-organic was superimposed. In *Fig.* 438 *B* it will be seen that the interossei and lumbricales of the fourth and fifth fingers are not fully extending the second and third phalanges.



FIG. 438*A*. - Overaction of the extensors and flexors of the wrist and of the extensors and long flexors of the fingers, with weakness of the interossei, following a lesion of the ulnar nerve (*Case* 6).



FIG. 438*B*.—The same case after training. Note the position of the ring and little fingers.

Case 7.—**Reflex spasm of the flexors of the wrist, interossei, and adductor of the thumb after a gunshot wound of the forearm** (*Figs.* 439 *A*, *B*).

Pte. J. C., was wounded in the left forearm on June 28, 1918, with fracture of the ulna, and on Aug. 20 was admitted to the 2nd Northern General Hospital.

SURGICAL WARD.

Aug. 20.—Wound through inner margin of left forearm about the middle. Wrist flexed 45°; cannot be extended. Fingers straight, thumb adducted. Marked functional element. Fracture of ulna united. Elbow normal. No voluntary movement in hand.

RE-EDUCATION DEPARTMENT.

Aug. 24.—Spasm of adductor pollicis and interossei. Rigid inco-ordination of whole limb (not much of shoulder and elbow).

Sept. 18 (*Nerve Report*).—Possibly a slight ulnar lesion, as there is a little hypo-æsthesia on fifth digit, but all muscles, median and ulnar, react to faradism. The physiopathic element is the chief factor in causing the disability.

Oct. 14.—Spasm not so marked.

Oct. 21.—For two months' leave, as curative measure.

Jan. 4, 1919.—Greatly improved. No flexor or adductor spasm of any kind, but extensors have not yet fully recovered their tone. Should soon be well.

Jan. 18.—All movements now good. Full extension of fingers and wrist simultaneously.



FIG. 439*A*.—Reflex spasm of the flexors of the wrist, interossei, and adductor of the thumb, after a gunshot wound of the forearm (*Case* 7).



FIG. 439*B*.—The same case after training.

There are two points of interest in this case: (1) The condition was a reflex spasm (Babinski's 'physiopathic'—compare *Case* 16); (2) When once the patient knew the treatment, and was found to be working well at it, he was given two months' leave, at the end of which he was almost well.

Case 8.—**Flaccidity in flexion of the fingers and in flexion and extension of the thumb after compound fracture of the radius and injury to the flexor pollicis longus.**

Major J. C. P., age 35, was wounded in the right forearm and left leg on Nov. 10, 1917, and was admitted to the 2nd Northern General Hospital on Feb. 3, 1918, suffering from a disability of the hand.

Surgical Ward.

Was hit on wrist by a piece of high-explosive shell, and sustained a compound fracture of the radius.

Feb. 5 (*X-ray Report*).—Union has taken place to some extent. One or two small sequestra present.

Re-education Department.

Feb. 13.—Large gunshot wound involving the right radius above the wrist. *X*-rayed. Radial anæsthesia. Pronation and supination: Can pronate almost fully, but supinate only half way; passive pronation and supination: each about three-quarters. Wrist: Movements good. Thumb: Flexion almost nil, although flexor pollicis longus can be felt contracting well in forearm; all extensors act slightly, but without much result, for want of counter-tension; opposition good. Fingers: Extension good; flexion very fair, but incomplete because of organic stiffness; abduction and adduction excellent.

Feb. 22.—Fingers: Flexion much better. Thumb: Extension powerful; flexion of first phalanx good, opposition good. Hand is therefore now about as useful as it can be in the presence of the organic injury to bone and to flexor pollicis longus.

March 5.—Transferred to surgeon.

The disability in flexion of the second phalanx of the thumb was due to the organic injury to the flexor pollicis longus. The inability to extend the thumb or to flex its first phalanx was probably originally due to the shock of the wound, and it was kept up by the persistent extension of the thumb, and by the loss of counter-tension in the flexor, as well as by disuse through the mistaken idea that the whole trouble was organic (as the patient himself freely admitted). The inability to flex the fingers was doubtless begun by the shock, kept up by splinting, and ultimately complicated by the organic stiffness.

The treatment consisted in explaining how the disability arose, and then in combined passive movement and voluntary effort along the lines previously indicated. In this, as in so many cases, the duty of re-education was to banish the non-organic trouble, after which the patient could be handed over to the surgeon for possible further treatment. This patient was neither malingering nor a hysteric. Babinski objected to the term 'hysteria,' and sought to replace it by 'pithiatism,' which he applied to any condition which could be produced by suggestion, and cured by the same means. This would, however, include most of the habits in life, good, bad, and indifferent; thus, there must be few who have ever begun or given up the habit of tobacco-smoking except under the influence of suggestion. Some would retain the term hysteria, but limit it to symptoms produced by suggestion, and similarly curable; but this only transfers the difficulty to the term 'symptoms.' Many disabilities which are still labelled hysterical are simply muscle habits, which have been acquired and retained in quite as rational a manner as some of the everyday habits of modern civilization. The really serious difficulty, however, is the unpleasant suggestion of the effete term 'hysteria.' The time will never come when patients will tamely submit to be called hysterical simply because their medical adviser has learned to water the term down until it has very little solid content.

Case 9.—**Partial flaccidity of the whole upper limb after a gunshot wound of the arm, followed by organic paralysis of the musculocutaneous nerve through constriction by cicatricial tissue.**

Cpl. M. W. B., age 22, was wounded in the right arm and back on Aug. 16, 1917, and was admitted to the 2nd Northern General Hospital on Oct. 17.

Surgical Ward.

Oct. 17.—Flesh wounds of right arm and back. Wounds all healed. No operation. Right hand somewhat cyanotic. Abduction of arm limited. Functional?

Re-education Department.

Oct. 19.—Wounds of neck and back. Also one on dorsum of arm. Shrapnel still in. Whole limb is feeble. Shoulder: All movements feeble and incomplete—e.g., abduction is very poor. Elbow: Flexion and extension slow, hesitating, and incomplete. Wrist and hand: Complete movements, but feeble. With re-education the movements are less hesitating, stronger, and more complete.

Oct. 23.—In some ways the case suggests an organic lesion.

Oct. 27 (*Nerve Report*).—All muscles of every group give good faradic response.

Oct. 28.—Absolutely no voluntary response in biceps. Ordered simultaneous faradism for all muscles of the arm (musculospiral and musculocutaneous nerves).

Nov. 5.—Hand is improving.

Nov. 9.—Forearm and hand and triceps improving.

Nov. 20 (*Nerve Report*).—Biceps and brachialis anticus show an organic nerve lesion.

Dec. 15.—The limb is now very much improved. The movements of shoulder, wrist, and hand are excellent, but the elbow is still weakened in flexion by the loss of power in the biceps.

Dec. 17 (*Nerve Report*).—Biceps gives a little faradic response now. No sensory loss.

Dec. 22.—Biceps shows no voluntary response yet. Ordered a caliper splint which allows extension to 90°.

Jan. 12.—Now has splint. As this is an organic lesion of the biceps, it would be enough if patient turns up in the re-education department once a month for supervision.

Feb. 27.—Biceps now shows voluntary response. *X* rays show foreign body (? shrapnel) interfering with the musculocutaneous nerve.

March 9.—Operation for removal of foreign body decided on.

March 11.—Operation, ether. Foreign body found between internal and lesser internal cutaneous nerves and removed. There were adhesions around musculocutaneous nerve. These were freed, and vaseline was smeared on.

This case is curious in that, while the purely functional flaccidity was being rapidly cured, an organic nerve paralysis developed through constriction by cicatricial tissue, and then gradually cleared up of itself, the foreign body being finally removed in order to prevent further trouble.

Case 10.—**Almost complete flaccidity of the whole upper limb following a severe wound of the shoulder.**

Pensr. W. R., age 22, was wounded in the right shoulder on July 2, 1916, and discharged from the service. He was admitted to the 2nd Northern General Hospital on Sept. 17, 1917.

Re-education Department.

Sept. 17.—*Previous History*: On July 2, 1916, was hit by shrapnel in region of right shoulder. At once lost use of his whole right upper limb, and has never since been able to use it in any way, except that there was a slight range of movement in flexion and extension of the fingers.

Present Condition: (1) Large scar with centre about 1¾ in. below middle of clavicle; shrapnel which caused the wound was removed by same route. (2) Deep round scar in front of shoulder about 2 in. below acromion; shrapnel entered here and passed backwards and inwards. (3) Large scar in outer part of infraspinous fossa; says shrapnel of scar (2) was taken out or came out here. (4) Scar 2 in. by 1 in. lying longitudinally along groove on outer side of biceps, with centre about 5 in. above elbow; says this was an incision for suppuration. There is no obvious reason why the wound should have given rise to the disability if it is due to organic lesion of the nerves. The nerves were examined at the 5th Southern General Hospital, and were stated to be 'all right.' Scars have been healed a long time, except the one in front of shoulder, which has been healed only three weeks. The limb hangs limp by the side. No active movements, except that there is very slight flexion and extension of the fingers. The phalanges are all slightly flexed, so that the terminal phalanges lie in a plane at right angles to that of hand. The range of movement of the tips of the fingers is only about an inch.

Sept. 20.—Is showing slight signs of improvement in fingers.

Sept. 24.—Improving. All the joints have fortunately remained supple, and as he is anxious to get well, he should improve rapidly.

Sept. 27.—Can abduct arm slightly, flex elbow slowly for some distance, flex and extend wrist to some extent, and flex and extend and abduct and adduct fingers slowly but almost perfectly as far as range is concerned.

Oct. 6.—Improving well.

Oct. 15.—Still better.

Oct. 25.—Can do almost everything but raise shoulder above horizontal. Because of weakness of humerus it is undesirable to try for much more. The *x*-ray photograph shows (1) an oblique fracture of the shaft of the bone about the level of the surgical neck, and (2) a rounded notch involving about half the diameter of the shaft, evidently marking the point at which the projectile had forced its way through the bone.

Nov. 1.—Cured.

This case, rightly or wrongly, suggested to the writer that a 'muscular anæsthesia of disuse' may sometimes be responsible for the persistence of flaccidity. In the monkey, section of all the posterior (sensory) nerve roots to a limb results in motor paralysis. Is it not possible that something like this may take place in a wounded limb which

first suffers a severe shock and then is kept quiet for a long time by means of splints, and also by the patient's ignoring all reflex stimuli, and suppressing all voluntary impulses. Because the muscles do not contract, the sensory nerve-endings within them and their tendons are never stimulated. The muscles are in fact in a condition resembling sleep. When finally the splints are taken off, and the limbs may once more be moved, the muscles can only be made to contract by order of the higher centres. But, for their knowledge and control of the muscles, the centres depend upon the sensory nerve-endings themselves, and these remain quiescent until the tension within the muscles is varied by their contraction. The muscles must therefore be waked by both passive and voluntary stimuli. The first contractions are chiefly due to the direct and reflex stimuli of the passive movements, but the will gradually gains more and more control.

Case 11.—**Limitation in abduction of shoulder (through spasm) after a fall. Aphonia.**

Pte. J. L. was admitted to the 2nd Northern General Hospital on Nov. 28, 1918.

SURGICAL WARD.

Nov. 28.—Accidental fall during physical training. Now soft crepitus felt over superior angle of scapula. Shoulder h ld stiff by muscular spasm. No bone injury.

RE-EDUCATION DEPARTMENT.

Dec. 7.—Voluntary abduction of shoulder to 50°, passive to 85°. Spasm of pectoralis major and teres major. Crepitus above spine of scapula. Scar of incision beside upper angle of scapula.

Dec. 14.—Voluntary abduction to 80°.

Jan. 2, 1919.—Now good action of the deltoid, but rotation of the scapula is very poor. None of the muscles of the shoulder are working well, except perhaps the upper part of the trapezius.

Jan. 14.—Has had a cold. Aphonia for a week. Still speaks in a whisper. Throat rather sore. Not using abdominal muscles at all. With training, he recovered his voice in forty-five minutes.

Jan. 15.—Pain in back, right and left scapular regions. Rheumatism?

March 12.—Abduction of shoulder to vertical. Cured?

In this case there is undoubtedly an organic cause of the crepitus, which is situated apparently in the interval between the muscles of the limb and those belonging to the trunk. This type of crepitus has been observed in several cases. It may possibly be due to a 'rheumatic' fibrositis. It sometimes follows fracture of the scapula, and in this very case the scapula had been explored for fracture in the region of its upper angle. The aphonia is the first case on record in the department. In civil practice the writer has always relied upon the application of lactic acid to the vocal cords, a method which is usually successful in a few minutes. In this case, however, it was decided to apply the general principles upon which the whole work of the department is based. The aphonia was due, not to inability to approximate the cords or to use the muscles of the mouth, thorax, or abdomen, but to an inco-ordination of these groups. Treatment therefore consisted in training him to use each group in the proper way at the proper time. It is a question of team work.

Case 12.—**Tonic adduction of the arm complicating ankylosis of the shoulder-joint.**

Pensr. T. R., age 60, had his left humerus dislocated in November, 1915. This remained unreduced, and he was finally admitted to the 2nd Northern General Hospital on Jan. 15, 1919.

SURGICAL WARD.

Jan. 15.—Arm held stiffly at side, but shoulder can be abducted passively through about 18°. Shoulder-girdle muscles, especially deltoid, very much wasted. Biceps and triceps fairly well nourished. Forearm and hand normal. *X-ray Report*: Head of humerus has been partially dislocated upwards, and is now ankylosed to the glenoid cavity.

Jan. 16.—In addition to his scapulo-humeral ankylosis, he holds his scapula firmly fixed by means of his pectorals and teres muscles.

RE-EDUCATION DEPARTMENT.

Jan. 18.—All movements of shoulder extremely limited. With training he can flex to about 60° and abduct to about 70° voluntarily. Severe pain.

Jan. 24.—Voluntary flexion 90° and abduction 80°. The first night after treatment he says he could scarcely sleep for pain. Now he has very little. Can now get his left hand to the back of his neck, for the first time for two years.

Jan. 30.—Cured. Transferred to surgeon.

The non-organic disability was rapidly cured, and then the patient was referred to the

surgeon for possible surgical measures. The patient states that he had done twenty-two years' service, and that he rejoined for this war. During the erection of a bridge a plank fell upon his shoulder. It is possible, therefore, that the acromion was fractured and slightly dislocated downwards. The movement of the arm became more and more limited, until at last it remained fixed at his side.

II. LOWER LIMB.

Case 13.—**Flaccidity of the long extensors of the toes after a wound of the foot causing extensive ankylosis of the tarsus (*Figs.* 440 *A*, *B*).**

A.-B. J. A. R., age 20, was wounded in the right thigh and on the dorsum of the foot on Dec. 27, 1917, and was admitted to the 2nd Northern General Hospital on July 22, 1918.

Surgical Ward.

July 22.—Large scar on posterior and inner aspect of lower third of right thigh. Knee has free range of motion. Scar on dorsum of right foot and inner aspect of ankle. Ankle free, full range of motion. Toes and foot rather stiff. No power of dorsiflexion. *X*-rayed.

July 26 (*Nerve Report*).—A degree of power in all these muscles. The dorsiflexors are weakest, probably owing to long inactivity and the septic condition of wounds in the neighbourhood. There is some adhesion of the outer tendons of the extensors of the toes.

Sept. 5 (*Nerve Report*).—Suggest removal of scars and freeing of tendons. The whole case seems to be one of minor damage, progress halting from presence of scar, pain, and adhesion.

Re-education Department.

Nov. 21.—Tibialis anticus working well, but little or no voluntary power in extensor digitorum longus, peroneus tertius, and other peronei.

Dec. 3 (*Surgeon's Report*).—Stay in bed until ulcer is healed.

Dec. 12 (*Surgeon's Report*).—Ulcer almost healed.

Jan. 3, 1919.—Ulcer of thigh not yet healed.

Jan. 15.—No inversion or eversion. This appears to be organic. *X*-ray ordered.

Jan. 16 (*X-ray Report*).—Ankylosis of most of the tarsal and all the tarsometatarsal joints.

Jan. 22.—Now has good extension and flexion of ankle and toes, so that he may well be taken over by the surgeon.



A *B*

Fig. 440.—(*A*) Flaccidity of the extensors of the toes after a wound of the foot causing extensive ankylosis (*Case* 15). (*B*) The same case after training.

Fortunately the ankylosis had taken place in good position, so that with good flexion and extension he can walk well. Further training of the evertors would have been useless.

Case 14.—**Partial flaccidity of the foot after a fall into a shell-hole.**

Pensr. S. C., age 37, fell into a shell-hole in February, 1916. He was admitted to the 2nd Northern General Hospital on Dec. 3, 1918, and at once referred to the re-education department.

SURGICAL WARD.

Dec. 3.—Fell into a shell-hole with a motor cycle. Next morning 'no use' in right leg, but he managed to trail himself to a hospital without the aid of a stick. Present condition purely functional. Peronei working, though weakly. Fair dorsiflexion of ankle. He walks badly on the outer side of the foot, with sole inverted.

RE-EDUCATION DEPARTMENT.

Dec. 5.—At first the whole right limb was 'almost useless.' Gradually improved, but now walks very badly on the outer border of the foot. Very slight dorsiflexion of ankle (toes rise about 1 in.). Only slight flicker of toes with long extensor. No voluntary eversion, and almost no inversion, of ankle. With training he rapidly recovers considerable dorsiflexion, eversion, and inversion.

Dec. 12.—Requires light boots.

Dec. 19.—Has proper boots and now walks perfectly. No one could tell which had been the defaulting limb.

This case illustrates a type in which 'excitation' of the foot is sometimes very effective. Hyperextension of the toes to the degree of causing pain rouses the muscles through a painful reflex. The dorsiflexors of the ankle and the extensors of the toes respond at once, and with appropriate passive movement and voluntary effort the peronei soon follow suit. Even then, however, the patient may persist in walking on the outer border of the foot. This is a pure bad habit, and may be seen in cases where from the first every muscle pulls normally except in the act of walking. The treatment consists in explaining the habit, and then in getting the patient first to flex his thigh and leg, while at the same time dorsiflexing and everting the foot ; and then to extend the thigh and leg, keeping the foot dorsiflexed and everted. The patient often inverts the foot before it reaches the ground, in which case he is likely to be rapidly cured. Sometimes, in order to get him to put the weight on the inner border of the foot, it is necessary for him to walk with the thigh abducted and the knee slightly flexed. This gives him a very awkward gait, but it will probably convince him that the foot can be kept everted even when supporting the body-weight. When training begins, care should be taken that patient has a light pair of boots, the soles of which are not unevenly worn down ; and if he wears rubber heels, these must not be round and loose as is so often the case, but they must be heel-shaped and firmly attached all over.

Case 15.—**Tonic inversion of the foot in walking, and flaccidity of the peronei, owing to a painful scar on the sole.**

Pte. A. C., age 22, was admitted to the 2nd Northern General Hospital on Nov. 27, 1917, with a painful scar on the left sole and disability in walking.

SURGICAL WARD.

Nov. 27.—Healed wounds of left thigh and leg. Healed wound of sole of foot. Foot is spasmodically contracted in inversion, so that he walks on its outer side. Calf muscles contracted.

Dec. 11 (*Nerve Report*).—This is a case of reflex inco-ordination due to local causes. There is no organic injury to the nervous system, higher or lower.

RE-EDUCATION DEPARTMENT.

Dec. 15.—As he lies in bed, there is good dorsal and plantar flexion of ankle, but peronei are not working very well. He walks on outer border of foot, to save a tender scar on inner side of sole.

Jan. 5, 1918.—The peronei are now working, so that the whole foot is normal in its muscular apparatus. There is no spasm, flaccidity, or clonus as he sits or lies with the foot at rest. On walking, the foot is markedly inverted, but this is purely to save pain in the scar. Re-education is no longer required.

In this case pain was responsible for the production and continuance of the disability. The deliberate suppression and neglect of the peronei resulted in complete loss of control, so that even when lying on a couch he could not evert the foot. Unless the painful scar was removed, relapse was certain.

Case 16.—**Tonic inversion of the foot, with œdema of the foot and leg, after gunshot wounds of the leg.** (*Figs.* 441 *A, B.*)

L.-Cpl. G. M. was wounded in the left leg on Nov. 20, 1917, and admitted to the 2nd Northern General Hospital on June 13, 1918.

Surgical Ward.

June 13.—*Previous History:* Gunshot wound of left leg, no fracture, on Nov. 20, 1917. Foot has been swollen and painful. No operations. Still foreign body in leg. Wounds healed about February, 1918. Foot was put into plaster case for twisted condition. Removed after three weeks, but no good effect. *Present Condition:* Foot now inverted, swollen, and very painful. All four small toes drawn down by flexors. Tendo Achillis much contracted.

Re-education Department.

Aug. 26.—Foot can be passively everted with much effort. Great œdema of dorsum of foot and even of whole leg up to the knee. Blue and cold.

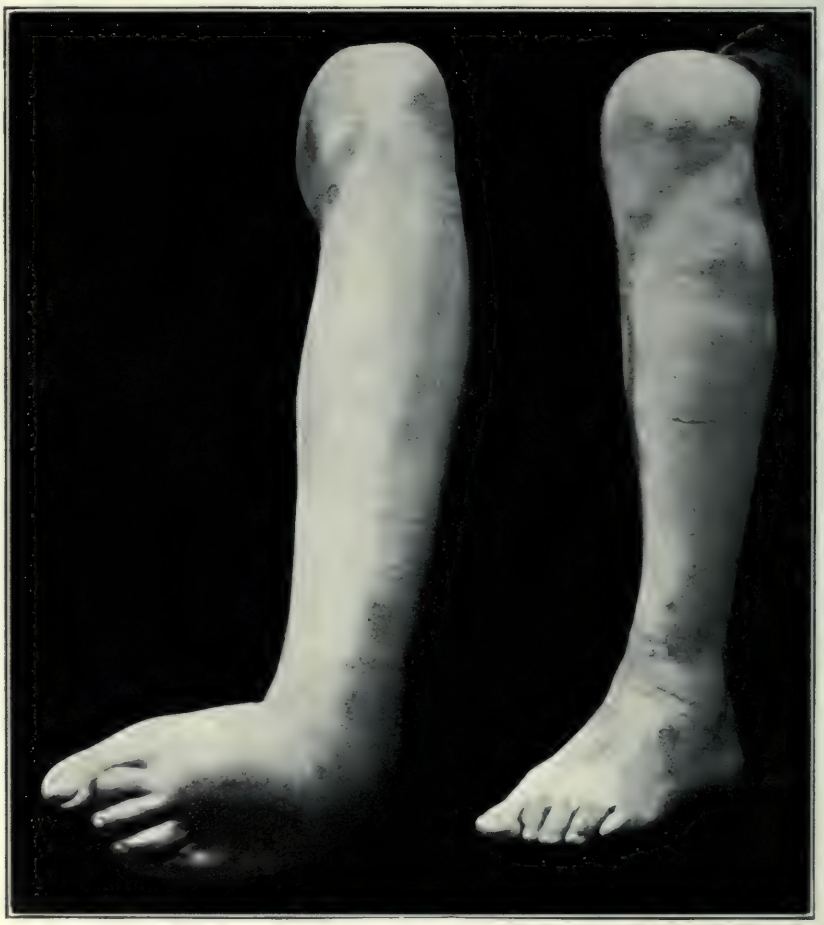
Oct. 28.—Colour better. Swelling much less, and not nearly as much spasm. Slight voluntary power in toes and ankle muscles.

Nov. 18.—Much more relaxed. Gaining voluntary power in extensor longus hallucis, and slightly (?) in extensor longus digitorum. Spastic flexors relaxing. Swelling less and colour improved.

Nov. 30.—Œdema almost gone. Foot good colour, and considerable voluntary power—e.g., he can bring the foot into fair position—but the tendo Achillis and its muscles are still too tight. Can now wear a boot with eversion chain.

Dec. 17.—Gradually improving.

Jan. 10, 1919.—Should soon be able to leave hospital.



A *B*

Fig. 441.—(*A*) Tonic inversion of the foot, with œdema of the foot and leg, after gunshot wounds of the leg (*Case* 16). (*B*) The same case after training.

This type of case Babinski has termed 'physiopathic,' and he has detailed numerous signs by which such cases may be distinguished from purely functional ones—as, for example,

vasomotor disturbance, increased irritability of the muscles to direct mechanical stimulation, prolonged contraction, and so on. Although Babinski thinks ultimate recovery likely, he does not appear to consider treatment of much value. There is no doubt, however, that, whatever may be their origin, these cases sometimes respond to treatment very well. At the 2nd Northern General Hospital, little difference is made in their treatment, although dried extract of thyroid (? parathyroid) gland has sometimes seemed to be of value.



FIG. 442.—(*A*) Eversion chain, crossed, with spring. (*B*) Eversion chain, uncrossed. ½ The chain passes through the spring, and in this figure it is taut.

In all forms of drop-foot, and more particularly in those due to a nerve lesion or where there is tonic inversion, it is desirable to evert the foot well. This can only be done by a pull acting in front of the mid-tarsal articulation. For this purpose the writer has added to the apparatus in general use in the hospital an eversion chain, which may be described as 'arising from' an upright on either the inner or the outer side of the leg, and being 'inserted into' a metal attachment on the boot opposite the base of the fifth metatarsal (*Fig.* 442 *A*, *B*). In some cases the chain acts better from an outer upright, and sometimes better still when the 'origin' is at the level of the upper border of the boot. A spring is often useful, and if the chain be passed through it and so attached to it as to leave two or three links relaxed within the spring, then, when the spring has yielded to its proper length, the chain becomes taut and prevents overstretching.

Case 17.—**Flaccidity of the foot and pelvic drop after a gunshot wound of the ankle.**

Pte. W. S. was admitted to the 2nd Northern General Hospital on July 30, 1918, with a healed gunshot wound of the left ankle-joint and drop-foot.

SURGICAL WARD.

Aug. 1.—Scar on lower half of left leg posteriorly—the point of entrance of the bullet. Scar on dorsum of foot and front of ankle, from operation. Healed about one month. Foot is dropped, with no power of dorsiflexion.

Aug. 13 (*Nerve Report*).—No nerve injury. All muscles will work with persuasion.

RE-EDUCATION DEPARTMENT.

Aug. 29.—No muscles pull to-day.

Sept. 6.—All muscles contract in ankle and foot.

Oct. 4.—Extensor hallucis pulling better.

Nov. 14.—All muscles pulling well, and movements of foot quite good. Still complains of pain in ankle, which makes him limp, and there is still pelvic drop to the right.

Nov. 23.—Pelvic drop has improved, but very difficult to treat, because he cannot put full weight on the foot.

Nov. 29.—Pain rather better.

Dec. 3.—Very little pain. This comes on after he has been resting the limb, and passes off with exercise. Now almost well. Should recommend two months' leave.

The pain in the foot interfered with and prolonged the treatment. There is no valid reason for supposing that it was purely functional.

In the treatment of pelvic drop when drop-foot is present, an eversion chain is a great help, since it stabilizes the foot (see *Fig.* 442).

Case 18.—**Limitation in flexion of the knee after a gunshot wound of the hamstrings.**

Bombr. H. P. was admitted to the 2nd Northern General Hospital on Oct. 10, 1918, with a severe wound of the back of the right thigh.

SURGICAL WARD.

Oct. 10.—Cicatrix along posterior aspect of right thigh. Small discharging ulcer in centre. Large amount of scar tissue. Marked twitching of thigh muscles. Marked tenderness in region of scar. Not able to extend leg beyond 125°. Slight power in extension and flexion of toes. Drop-foot splint.

Oct. 17.—Thomas's knee caliper. Right sole and heel to be raised one inch.

Oct. 26.—Minor lesion of external popliteal branch of sciatic nerve. All muscles are working, and are in a good state of nutrition.

Nov. 29.—Acute tenderness over scar.

RE-EDUCATION DEPARTMENT.

Dec. 13.—Condition appears to be non-organic. If so, he should do well. At the same time there is considerable loss of muscle tissue. The Thomas splint and thick sole and heel should be removed. Later: After an hour's treatment, he is at times able to straighten the knee voluntarily, and he walks much better. Massage to be stopped.

Dec. 16.—Doing well. To have light boots.

Jan. 6, 1919.—Walks with knee straight, but there is tension on the scar, and it keeps breaking down in the centre.

Jan. 10.—Would surgeon consider plastic operation?

There was pain on movement, and much loss of muscle tissue, and tension on the scar both superficial and deep. This made it difficult for him to recover full extension of the knee, and equally difficult to retain it, an exceptionally strong effort of the will being required both to contract the quadriceps and to relax the hamstrings. In such a case the tension should as far as possible be relieved by surgery, to reduce this effort to the normal.

Case 19.—**Limitation in flexion of the knee and pelvic drop, after a gunshot wound of the leg.**

Cpl. P. S. was wounded through the right leg on Aug. 11, 1917, and was admitted to the 2nd Northern General Hospital on April 9, 1918.

SURGICAL WARD.

Incomplete extension of knee (to within 30° of straight), and dorsiflexion of ankle. Foot is weak. Walks slowly with a limp. Small scar over calf.

April 16.—Scar stretched without much difficulty under ether. Knee put into extension, foot in dorsiflexion.

RE-EDUCATION DEPARTMENT.

May 25.—Slight limitation in flexion of knee. No disability of foot. Marked drop of pelvis on the left. When this is cured, gait will be normal. He now walks on his toes, but with special pelvic exercises he does well.

May 28.—Now scarcely a limp.

In this case the shock of the original wound probably caused a flaccidity of the right limb, which persisted in the abductors of the hip, and so led to a pelvic drop on the left side, the apparent increase of length in the left limb being compensated by walking on the right toes, which was all the more necessary when the knee was flexed. The pelvis is treated as follows. By means of a model the mechanism of the disability is explained to the patient, and then by alternate elevation of the hips and by simultaneous abduction and adduction of the limbs to right and left alternately, he is shown that either limb can be made to appear the longer or the shorter, according to their position in relation to the pelvis. He is then trained (1) on his back : (*a*) to elevate the hips alternately, with the lower limbs fully extended ; (*b*) to flex the lower limbs alternately (hip, knee, and ankle) ; (*c*) to combine the two previous exercises. He now (2) stands up, and is trained : (*a*) to 'mark time,' with full elevation of the hips and flexion of the hips, knees, and ankles ; (*b*) to continue the previous exercise, but stepping out a little and gradually moderating the elevation and flexion ; (*c*) to alight on the heel, advance on the sole, and step off from the toes. In a few cases a single lesson cures the bad habit ; but usually some after-training is required, while a few cases show little response.

Case 20.— **Flaccidity of the quadriceps and pelvic drop after a gunshot wound of the knee with rupture of the infrapatellar ligament.**

Pte. C. P., age 30, was wounded on March 28, 1918, and admitted to the 2nd Northern General Hospital on July 26.

Surgical Ward.

July 26.—Left knee shows healed scar just below patella and over infrapatellar ligament. Scar is very painful. No power in quadriceps. Whole leg must be supported. Slightest passive movement of knee-joint is painful. On palpation, the only painful spot is the scar.

Aug. 15.—Operation, ether. Infrapatellar ligament found torn away from its insertion. Freed and sutured.

Sept. 10.—Foot can be raised from the bed. Up and about on crutches.

Sept. 24.—Knee can be flexed to right angle.

Oct. 15.—Cannot extend leg yet.

Re-education Department.

Oct. 24.—Quadriceps is the cause of the disability now. Little or no voluntary contraction. Full range of passive movement without pain. Walks without knee flexion, and uses two sticks.

Nov. 15.—Quadriceps has now distinct power, but functions poorly. Patient still requires two sticks. With training he can extend the knee much better. Has quite a fair kick, and he can walk a little way without support.

Nov. 19.—Improved.

Nov. 29.—Slight drop of pelvis on the right.

Jan. 8, 1919.—Limp almost imperceptible.

In such a case as this, treatment of the functional disability must be postponed until the surgeon has remedied the organic defect. It is often very difficult to decide whether the disability is organic or functional, or mixed ; and, if mixed, what the first treatment should be, surgery or re-education.

Case 21.—**Flaccidity of the quadriceps and pelvic drop after gunshot wounds of the thigh.**

Pte. C. I. was admitted to the 2nd Northern General Hospital on Oct. 22, 1918, walking on crutches.

Surgical Ward.

Oct. 25.—Two scars on left thigh. Whole limb wasted. Considerable limp, with pain referred to front of patellar attachment.

Re-education Department.

Oct. 26.—Pain just above patella on movement of knee. All muscles of limb and foot acting, but quadriceps quite feeble at all times. In walking, patient limps badly, using right limb almost entirely to carry body-weight, and keeping left knee partly flexed. Non-organic weakness of quadriceps seems entire cause of disability.

Nov. 1.—To have light boots.

Nov. 8.—Gait improved.

Nov. 14.—Ung. methyl salicyl. for left knee. Exercises for right pelvic drop.

Nov. 21.—Walks without support quite fairly well. Quadriceps excellent.

Nov. 22.—Very marked improvement.

Nov. 29.—Cured.

The pain in this case vanished, and the function of the limb was completely restored. Light boots are usually necessary, and methyl-salicylate ointment is sometimes useful. It might be mentioned here that in one or two cases there has been some difficulty in deciding whether the shortening of the one limb was actual or only apparent. This may be settled by measuring in the usual way the distance on the two sides between the upper border of the great trochanter and the lower border of the internal malleolus. Since abduction of the limb lessens, whereas adduction increases, the distance between the anterior superior spine of the ilium and the internal malleolus, the above test may be confirmed in the following way. If the patient lies down with the limbs placed side-by-side, and if the perpendicular from the midpoint between the spines passes between the feet, then the difference in level of the internal malleoli is the difference in the actual length of the limbs. It is well to bear in mind that organic shortening is shown by a drop of the pelvis on the side of the injured limb, whereas pelvic drop due to flaccidity is usually on the opposite side. Both conditions may of course be present.

Case 22.—**Incomplete flaccidity of the whole lower limb following a bullet wound of the thigh, and complicated by fluid in the knee-joint.**

Pte. C. B. was admitted to the 2nd Northern General Hospital on July 20, 1918.

Surgical Ward.

July 20.—Through-and-through bullet wound of right thigh. Some atrophy of thigh and leg muscles. Knee cannot be flexed beyond 100°. Tendency to equinovarus when foot is at rest. Pain extending down anterior aspect of leg. Can evert, invert, and dorsiflex foot quite well.

Sept. 6.—No power of dorsiflexion. Anterior tibial group of muscles acting very sluggishly, if at all.

Sept. 13 (*Nerve Report*).—Not much in the way of nerve injury. All muscles react readily to faradism.

Re-ed cation Department.

Sept. 21.—Disability of entire limb, but much improved. All muscles act with excitation, but there is some inco-ordination in voluntary movement.

Oct. 5.—Almost no power in ankle and toes. Very little in knee (feeble, hesitating); rather better at hip. A general flaccidity of the right lower limb (incomplete), with left pelvic drop. There is some fluid in knee, and patient complains that knee often gives way in walking.

Surgical Ward.

Oct. 11.—Effusion in right knee, limiting flexion.

Oct. 18.—General wasting of quadriceps and extensor structures about knee-joint.

Nov. 8.—No effusion in joint.

Re-education Department.

Nov. 16.—Foot is still very flaccid. Some voluntary dorsiflexion. Very little use of extensor longus digitorum and peronei.

Nov. 22.—All muscles of lower limb working well. Good extension of knee, good dorsiflexion and eversion of foot.

Dec. 13.—Quadriceps is still not so well developed as on the left side, but patient has complete control of the limb, and there is no pelvic drop.

The development of the fluid in the knee-joint showed that there was a considerable organic basis for the purely functional trouble, and for a time it made treatment impossible.

Case 24.—**Complete flaccidity of the lower limb accompanying wound of the quadriceps with subsequent overstretching.**

Pte. H. D., age 34, received a gunshot wound of the left knee on April 11, 1917, and he was admitted to the 2nd Northern General Hospital on Nov. 22.

Surgical Ward.

Nov. 22.—Small scar over upper part of patella, and small sinus two or three inches above joint on popliteal surface of thigh. Bits of bone are said to come out at times. No interference at joint with flexion or extension. Abnormal lateral mobility and rotation present. No abnormal antero-posterior mobility. No excess of fluid, patella movable, no points of tenderness, slight crepitus on flexion and extension. Apparently no power either to flex or extend the joint. There is a good deal of atrophy of thigh, less of calf; much weakness in flexion and extension of foot. *X*-ray ordered.

Dec. 1.—*X*-ray shows clean perforation.

Dec. 6 (*Nerve Report*).—No area of anæsthesia. All muscles respond to faradism and have voluntary power.

Dec. 14.—Popliteal sinus to be irrigated with eusol daily. Continue back splint to knee. Daily massage of anterior thigh muscles and hip muscles—avoiding region of sinus, and gently over knee—and of whole leg.

Dec. 21.—Sinus practically closed from bottom, and now only a small superficial granulating surface.

Dec. 29 (*Nerve Report*).—All muscles which control knee respond to faradism. They are much atrophied. Faradism of quadriceps ordered.

Jan. 1, 1918.—Wound healed.

RE-EDUCATION DEPARTMENT.

Jan. 18.—Complete disability of left knee. Quadriceps absolutely flaccid. Hamstrings flaccid, but semitendinosus shows some flickering. Cannot keep the leg vertical as he lies on his face. With re-education semitendinosus and biceps work better, and he can keep the leg up (with great difficulty). Quadriceps has been badly stretched.

Jan. 22.—Can keep his leg vertical quite easily when on his face.

Jan. 23.—Can hold leg up even when flexed less than 90°.

Jan. 25.—Can now as he lies on his face easily flex the knee from full extension through the full range. Quadriceps, however, is still absolutely refractory; there is not even a flicker, although tapping on the infrapatellar tendon produces a sharp contraction.

Feb. 10.—Improving.

Feb. 17.—Shown at Consultation Board. Quadriceps has been stretched above the patella.

March 8.—Sir Robert Jones orders caliper splint allowing 20° of flexion.

Reviewing this case nine months later, one cannot help wishing that one might take it in hand again in order to re-educate the quadriceps. It is just possible that later methods might have been successful.

CONCLUSION.

Detailed Diagnosis.—The functional is sometimes so elusive that no disability should be diagnosed as wholly organic without the most searching examination. One of his surgical colleagues recently told the writer that, in order to avoid overlooking anything, he now, when he sees a new case, always first asks himself, "Can there be anything functional in this?" It is not enough to form a general diagnosis. Every structure of the part must be examined. In most cases the problem is rapidly reduced within small dimensions, although within these limits it may be intricate enough.

Detailed Treatment.—Each muscle must be taught to function properly—that is to say, to contract and relax at will, and so, by acting at the proper moment with the proper degree of force, to secure complete co-ordination of all the muscles of the part. In a case of drop-foot, the man must be taught not only to walk and to raise the ankle, but also to make full use of the long extensors of the toes. In particular, in a mixed organic and functional case, the more crippling the organic disability, the more important may it be that the functional disability should be cured.

Mental Attitude of the Patient.—This is usually good. At first no doubt he is often sceptical, but this is only natural if he has for some time been under various forms of treatment with little or no result. On a bench in one of the lecture theatres in the legal department of the University of Edinburgh, a long-suffering student once carved the words, "How long, O Lord?"—and these seem to be the sentiments of many a patient who finds himself for the first time in the department. As a rule, however, he soon comes to see that if through wounds or physical or mental strain his muscles have fallen into bad habits, there is no reason why these habits should not be overcome with training. Above all, he realizes that while the training is directed by the staff, the muscles must be constantly disciplined by himself. Many of these men are very keen, and their steady but gradual progress would appear to justify the belief that there is nothing hysterical about their disability. The condition may be purely functional, but it is an abuse of language to apply to these men a term which has for centuries carried with it a more than half contemptuous suggestion of hyper-femininity.

Team Work.—The treatment of these cases is essentially a matter of team work. Before re-education, the case is seen by a surgeon; and incidentally it may be remarked that it would be no bad thing if the converse were more often practised, so that before

surgical treatment was begun the case were seen by a re-educator. If there is a doubt as to the involvement of a nerve in an organic lesion, a confirmatory report is obtained from the electrical department. After the wounds have healed, the surgeon will in some cases be called upon to restore the structures as far as possible to the normal before re-education is undertaken ; in others re-education may begin at once. In either case, when the one form of treatment has reached its limit, the other should be called upon to do what it can towards removing any residual disability. In this way the case may change hands several times, and the writer is glad to have this opportunity of expressing his hearty thanks to his surgical and other colleagues for their co-operation in the work.

Above all, however, he is indebted to Lieutenant-Colonel Littlewood, Officer Commanding the 2nd Northern General Hospital. It was Colonel Littlewood's insight into the needs of these cases which led to the formation of the department, and but for his confidence and encouragement in the face of many difficulties, the department might long ago have ceased to exist. The writer's thanks are also due to Colonel Littlewood for permission to publish the above cases from the records of the hospital, and to the Medical Research Committee, without whose financial aid the department would have been without photographs.

DIGESTION OF THE ŒSOPHAGUS AS A CAUSE OF POST-OPERATIVE HÆMATEMESIS.

By J. HOGARTH PRINGLE and JOHN H. TEACHER, Glasgow.

INTRODUCTION.

Post-mortem digestion of the œsophagus, and digestion of the œsophagus occurring during life or 'œsophagomalacia,' are described in the text-books of pathology. Slight degrees of the former condition are common; the latter is stated to be extremely rare, and the connection between it and vomiting of black material or actual hæmatemesis following operation appears to have escaped recognition.

Adami and Nicholls[1] mention œsophagomalacia as an agonal manifestation in cases of cerebral disease, and Shennan[2] refers briefly to post-mortem digestion of the œsophagus. Kaufmann[3] describes post-mortem digestion in sufficient detail, and states that slight degrees of it are common—a statement which we can confirm. *Intra-vitam* œsophagomalacia of great extent is said by this writer to be rare, but a few cases of 'ulcus a digestione' have been recorded. He describes a case of cirrhosis of the liver in which there were extensive digestion and perforation very like that seen in some of the present cases; there was thrombosis in the varicose veins which he regarded as of etiological importance. Perforation of varicose veins of the œsophagus in cirrhosis of the liver has frequently been seen by one of us, but is quite a different thing from the acute digestion with which this paper deals.

In considering the subject of post-operative hæmatemesis, one must exclude those cases in which the symptom follows upon some direct surgical interference with the stomach itself, and also that class of patient who suffers from a gastric or duodenal ulcer at the time of undergoing an operation for some altogether different disease. In the latter case hæmorrhage may begin from an old-established ulcer the existence of which has not been known, and which, in other instances, may perforate with disastrous results, should the accident not be recognized.

Apart from these cases, post-operative hæmatemesis is a symptom of great importance to the practical surgeon, and associated with serious danger to the patient. Fortunately it is not of frequent occurrence, for many patients who develop this symptom die. Although the death cannot always be said to be brought about by the hæmorrhage—as many of the patients are in a state of profound toxæmia and the amount of blood vomited is frequently small—still there are cases on record where large quantities have been vomited, which could only have hastened the fatal termination. On the other hand, those patients who recover after this symptom has developed, do so only after passing through a period which is extremely critical for themselves, and not less anxious for those responsible for their treatment.

The hæmatemesis usually sets in early after the operation: but in one of the cases here reported (*Case* 4), the patient vomited blood before the operation was carried out as well as afterwards—a fact of considerable importance in its bearing on this subject. In the majority of cases that have been recorded, the amount of blood vomited at one time has been small, and this is in accordance with our personal experience of these cases. The fluid ejected is usually extremely acid, and those patients who are sufficiently conscious to be able to express themselves, frequently complain of the scalding effect which it has upon the throat and lips.

Attention seems to have been directed to the subject in the first instance by Von Eiselsberg,[4] who in 1899 reported the cases of seven patients, five of whom had undergone

operations for hernia, and two for rectal carcinoma—all of them, however, involving the peritoneal cavity. In five of these cases hæmatemesis set in after operation, and three of them (hernia cases) recovered; of the other two, one (a hernia patient) died thirty-eight hours after operation, and at the post-mortem examination "recent gastric and duodenal ulcers" were found; the other patient (a rectal carcinoma) developed hæmatemesis on the second day and died on the ninth, and post mortem a "deep duodenal ulcer" was found which "appeared to be recent." In his remaining two cases no vomiting occurred at all, but both patients died; in one "about thirty gastric erosions" were found post mortem, while in the other case (a rectal carcinoma) "numerous recent hæmorrhages were found in the gastric mucous membrane." In six of the seven cases either the omentum or the mesorectum had been ligated, and Eiselsberg considered the source of the bleeding might be explained by a retrograde thrombosis or embolism of gastric vessels from the stump of the omentum or mesorectum, followed by necrosis and digestion of the area involved.

It is quite possible that in some of the cases that have been met with this explanation is the correct one; Wilkie[5] has shown by experiment that ulceration of the stomach can be produced in this way, and that a well-defined ulcer can develop within two days of causing the embolism.

Since Von Eiselsberg's paper was published, cases of post-operative hæmatemesis have been recorded which have gone on to a fatal termination, and in which erosions of the gastric membrane have been found post mortem. Again, other cases have been reported in which no cause for the bleeding, at any rate from the stomach, could be found after death. Rodman[6] has suggested that these cases might be due to sepsis and the alteration in the blood which results therefrom, in consequence of which the blood is capable of exuding through apparently intact mucous membrane.

The anæsthetic has been blamed by some writers, but beyond acting as a predisposing cause by exciting vomiting after operation, it does not seem to us to be likely to play any part in the process.

The clinical experience of one of us (J. H. P.) in this connection has to do with 18 patients, of whom 7 recovered after going through illnesses of the gravest possible nature, which must have proved fatal in every instance had it not been for the most excellent nursing which they received. The diseases from which these seven patients suffered were very varied in their nature, but 6 of them underwent abdominal operations—viz., for gangrene of gall-bladder, 2; thrombosis of the superior mesenteric vein, 1; umbilical hernia, 1; ovarian cystoma, 1; volvulus of bowel, 1; while the seventh patient had a mamma amputated for carcinoma: as these all recovered, it is impossible to say what may have been the source of the bleeding. Eleven of the patients died, and in 4 of these a post-mortem examination was not permitted (1 umbilical hernia with extensive resection of bowel, and 3 acute suppurating appendix cases). Post-mortem examinations were made in the remaining 7 cases. Of these, one patient was operated for what proved to be a ruptured ovarian cystoma, and post mortem the portal vein was found thrombosed, so that the vomiting of blood in this case must be looked on as analogous to that which occurs in cirrhotic liver; one was a case of gall-stones, and post mortem numerous erosions were found in the gastric mucous membrane; another was a case of acute appendicitis, in which no cause for the hæmorrhage was found in the stomach, and the œsophagus was not examined (neither of us was present at this examination). The remaining four cases are reported below rather more fully, for at the post-mortem examination no explanation for the onset of the hæmatemesis could be found unless it might be the state of the œsophagus.

From the pathological side, the observation which first aroused interest in the subject was the following. In 1909, at the Western Infirmary, Glasgow, one of us (J. H. T.) performed a post-mortem examination for Sir Hector Cameron on the body of an extremely well-built, well-nourished youth, who had died about ten hours after operation on account of acute appendicitis. The patient was very ill; and the appendix was found to be gangrenous; but so far as the post-mortem appearances in the abdomen were concerned,

a successful result might have been expected. The striking feature of the examination was the presence of destruction of the lower part of the œsophagus, the presence of slate-coloured fluid in the pleural sacs, and congestion and hæmorrhage in the lungs and softening of their surface in the neighbourhood of the œsophagus. There were also air-bells in the surface of the lungs which suggested interstitial emphysema in the affected areas. The appearance suggested digestion of the œsophagus and the adjacent parts. The stomach, in contrast with the œsophagus, presented healthy characters, with only the slightest degree of post-mortem digestion.

It was felt strongly that these changes had occurred during life, and had been the cause of the fatal result. Nothing in the way of inflammatory reaction (which would have proved the *intra-vitam* nature of the changes) was found, but the 'emphysema' and hæmorrhages were regarded as very suggestive. One of the later cases (*Case* 4—J. H. P.) fills this gap in the evidence, and we also feel that too little weight was given at the time to the hæmorrhages, which have now been observed in the substance of the œsophagus and in the lungs in a number of cases, as proof of the vital nature of the digestion of the œsophagus. Pneumonic consolidation in the neighbouring surfaces of the lung has also been found, but uncertainty is felt as to the significance of this: in some cases it might be part of a hypostatic pneumonia.

Fifteen cases have now come to post-mortem examination in which we consider it most probable that digestion of the œsophagus occurred during life. In 11 of these there was vomiting of brown or black material, or actual hæmatemesis. In 8 cases the condition in the œsophagus was advanced—destruction and perforation; in 7 it was early. In 8 cases there was no digestion of the stomach. In 7 there was slight digestion of the stomach. In 9 of the cases there had been operations, and we have added 6 cases in which there had not been any operation, but in which there were similar changes in the œsophagus. A number of cases of digestion of the œsophagus have been considered and omitted as being examples of post-mortem digestion.

We are much indebted to Sir Hector Cameron, Mr. Rutherfurd, Drs. Mackenzie Anderson, W. R. Jack, A. W. Russell, and Professor Munro Kerr for permission to publish the cases in which they were interested.

PARTICULARS OF CASES.

Case 1.—**Gall-stones. Pancreatitis. Excision of gall-bladder. Hæmatemesis. Early digestion of œsophagus. Hæmorrhages into wall of œsophagus.** (*Fig.* 443.)

M. B., female, age 24, was sent into the Royal Infirmary, Glasgow, under the care of Mr. Pringle on Jan. 14, 1914, as an urgent case, with the diagnosis of perforation of a gastric ulcer. It was stated by her friends that she had been in good health up to fourteen days prior to admission. At that time she was seized suddenly with severe epigastric pain, which was associated with vomiting. She remained in bed for five days, then resumed work, feeling well until the day of admission at 10 a.m., when she experienced a severe sharp pain in the epigastric region. She worked for one and a half hours after its onset and then went home. She vomited on two or three occasions some greenish material before she came into hospital. The bowels have been acting regularly.

The patient was very ill, the abdomen board-like and very tender. Both flanks were resonant on percussion. Lungs healthy. An immediate operation was carried out. The peritoneal cavity contained some brown turbid fluid. The omenta and mesenteries showed evidence of fat necrosis. The gall-bladder and common duct were packed with calculi. The pancreas felt extremely hard and had a deep yellow colour. The gastrohepatic omentum was much thickened and very œdematous. The gall-bladder was excised, the common duct opened, a number of stones removed, and a drain tube sutured in. The pancreas was incised freely, a quantity of dirty brown fluid escaping from the incision and cut surfaces, but the wound made in it bled freely. This wound was packed.

After operation the patient vomited continuously small quantities of dark black fluid which gave a blood reaction, and she complained of a pain behind the sternum. Just before death, which took place thirty-eight hours after admission, the vomited material was bright-red blood.

P.M. Report (No. 7606), Jan. 17, 1914.—The body was that of a young woman, well built and well nourished, but decidedly anæmic. Mid-abdominal operation wound and small drainage wound above the pubis. No jaundice.

Thorax.—The heart and the aorta presented healthy characters. The lungs showed marked

fine emphysema. The lower lobes of both showed an unusual degree of hypostatic congestion. There were no adhesions, and they stripped out quite easily, and no evidence of recent pleurisy could be made out; but it was only looked for after the recognition of the condition of the œsophagus.

Abdomen.—The liver showed advanced cloudy swelling and fatty change, being of a pale yellow colour with little of the usual red markings. The spleen was normal. The kidneys showed advanced cloudy swelling. There were numerous patches of fat necrosis scattered about the pancreas, and near the tail there was a breaking-down cavity with black necrotic appearance around the white necrosed fat. The pancreas was firm and of fairly normal colour. The duct was considerably wider than normal. The gall-bladder had been excised. The common bile-duct was much dilated and contained one faceted gall-stone, and the end of a drainage tube lay in it. The stomach was healthy in appearance. There was one small area of superficial hæmorrhage, but no post-mortem digestion. There was ulceration of the œsophagus of an irregular, slightly ragged type just above the cardiac ring, and there were many streaks of hæmorrhage in the mucous membrane running up to about the junction of the œsophagus and pharynx. In colour these were slightly dull, as if not absolutely recent. Some of the tissues surrounding the lower part of the œsophagus seemed gelatinous, and were of a dark-slate colour as if from the presence of altered blood. (*Fig.* 443.)

Case 2.—**Rupture of liver by accident. Abdominal section. Hæmatemesis. Advanced digestion of œsophagus.**

E. McC., male, age 18, was admitted to Glasgow Royal Infirmary under the care of Mr. Pringle on Dec. 16, 1914, complaining of severe pain across the abdomen. On the day previous he had been struck over the abdomen by the buffer of a pit hutch which jammed him against the wall of the pit. The abdomen was hard and board-like, both flanks resonant. Liver dullness was present. The patient was extremely ill. Pulse 108, temperature 104·4°, respirations 36.

The abdomen was opened at once in the middle line. This was followed by a furious flow of blood from an extensive rupture of the right lobe of the liver. The portal vein was clamped, and this immediately arrested the hæmorrhage. Blood in the peritoneal cavity was wiped out. The liver wound was packed with gauze. A tube was passed into the right renal pouch, and the clamp removed from the portal vein.

The patient rallied wonderfully, was well at night, and seemed to be so the next morning, but he died quite suddenly during the forenoon. It was thought that death might be due to a pulmonary embolism. The patient vomited on one occasion only, and that shortly before death, a small quantity of dark coffee-ground material being ejected.

P.M. Report (No. 7921), Dec. 18, 1914.—The body was that of a well-built, healthy-looking young man. There was a large median epigastric wound, with a second long wound running from it obliquely through the right hypochondriac region, approximately in the line of the edge of the liver.

Thorax.—The heart showed healthy characters. Embolism of lungs could not be made out. The right pleural cavity contained nearly a pint of blood-stained fluid, the left a smaller quantity of turbid, blood-stained, and very dark fluid. There was considerable anthracosis, and very marked hypostatic congestion of the lungs. The inner posterior aspect of the left lung was in a pulpy condition from advanced digestion of the parts close to the œsophagus. The condition became less on passing away from that neighbourhood, but was traceable over about a half of the lung, the posterior portions being alone affected. Where the condition was slight, there were small air-bubbles under the pleural membrane. There was a slight degree of the same condition on the inner and posterior aspects of the right lung, and in this area there were many superficial hæmorrhages. Whether the blood in the pleural cavities came from this condition or not, it was impossible to determine, but there was no gross injury of the lung to be seen. The œsophagus showed an advanced state of digestion, extending from immediately above the cardiac ring almost up to the pharynx. It was perforated at several places, and the surrounding areolar tissue was pulpy and full of black altered blood. The outer coat of the arch of the aorta was affected in this way, but the middle and inner coats were unaffected. The lower part of the trachea was intensely congested, but no perforation could be made out.

Abdomen.—The stomach presented healthy characters. It contained a considerable quantity of turbid greenish fluid, and there was no recognizable post-mortem digestion. There was a very extensive rupture of the liver, the main line of it being a laceration passing from back to front, and practically separating off the right end of the liver to the extent of about a quarter of the whole organ. This portion was in a state of necrosis. The vessels in the portal tract which had been clamped appeared none the worse. The rest of the liver showed marked cloudy swelling. The kidneys showed slight cloudy swelling. The spleen was rather large and soft. In the intestines there was nothing of note, but they were considerably distended.

Case 3.—**Anthrax with meningitis. Hæmatemesis. Advanced digestion of œsophagus.**

J. E., male, a brush-maker, age over 50 years, was sent to the Royal Infirmary on Aug. 19, 1916, with the diagnosis of a perforated gastric ulcer. From the scanty history available, the patient had suffered for many years from gastric symptoms—pain after food, with occasional vomiting—these symptoms recurring in cycles, with intervals of comfort. Since Aug. 16 he had been in bed, complaining of great pain in the abdomen, and with frequent vomiting.



FIG. 443.—Œsophagus from *Case* 1, showing the ring of ulceration ending sharply at the junction of the œsophageal and gastric mucous membranes, as well as numerous submucous and intramural hæmorrhages.

When admitted, the patient was unconscious, with pulse-rate 136, temperature 103·4°, and respirations 48 and stertorous. One of us (J. H. P.) saw the man shortly after he was brought to the ward. He was very restless. There was possibly a slight degree of rigidity of the abdomen in its right upper quadrant, but it was not great. There was extreme rigidity of his neck. The pupils were equal, of medium size, and their reaction to light was uncertain. The right optic disc was normal, and the left could not be seen—the eyes were constantly deviated to the right side. There was no evidence of any injury to the scalp or skull—no signs of bleeding from the mouth, nose, or ears, and there was no alteration in the percussion note over the skull. It was obvious he was suffering from some cerebral condition. He vomited or ejected small quantities—not more than a mouthful or two at any one time—of dark-brown fluid on five separate occasions. Death took place fourteen hours after he was admitted to hospital. The condition proved to be meningitis due to the *B. anthracis*.

P.M. Report (No. 8549), Aug. 21, 1916.—The body was that of a well-nourished old-looking man. There was very marked hypostatic congestion, and changes due to decomposition were distinct.

After the nature of the disease was made out, the exterior was very carefully examined, but no lesion of any kind could be found.

Thorax.—Both pleural cavities contained considerable excess of blood-stained fluid. The lungs were congested and œdematous, but not to a very striking degree. The trachea and bronchi were also congested. No local lesion could be found. The heart was soft and relaxed, and there was bloody staining of the endocardium. The œsophagus was found to have been digested, and seemed to have given way into the right pleural cavity, where there was slight digestion of the adjacent surface of the lower lobe.

Abdomen.—The liver showed marked cloudy swelling, and the blood in the vessels was full of gas-bubbles. The spleen was moderately enlarged, with tense glistening capsule, and ruptured during removal, exuding an abundant soft dark pulp. The kidneys showed some senile cirrhosis, cloudy swelling, and subcapsular hæmorrhages. The stomach contained a large quantity of dark-green fluid; there was considerable post-mortem digestion. There was, however, much more digestion in the œsophagus, the lining of which was black and broken down immediately above the cardiac orifice, the condition extending in diminishing degree for about five inches upwards. There was a small area of black slough immediately below the cardiac orifice. There were four small, fairly recent ulcers close to the pyloric ring. There was no intestinal anthrax lesion.

Head.—The brain was covered by a thin layer of blood occupying the interstices of the pia-arachnoid. There were myriads of small hæmorrhages on the surface of the brain and in the grey matter. The interior of the lateral ventricles was thickly studded with minute hæmorrhages, and the fluid was light red in colour. There were many minute hæmorrhages in the basal ganglia, and one hæmorrhage about the size of a kidney bean in the upper part of the right corpus striatum. The effused blood filled the lymph cisterns at the base, and was particularly abundant between the lobules of the cerebellum.

Films prepared from the fluid in the lateral ventricles and the blood in the pia-arachnoid both showed large numbers of short square-ended bacilli in chains closely resembling the anthrax bacillus, and profuse growth of that organism was obtained from the fluid in the lateral ventricles and from the pia-arachnoid, but not from any other organ or from the blood. Films of the spleen and blood showed numbers of single bacilli with definite capsules, apparently *B. aerogenes capsulatus*. Sections of the brain showed a true hæmorrhagic meningitis and numerous anthrax bacilli.

Case 4.—**Appendicitis with abscess and peritonitis. Hæmatemesis before operation. Advanced digestion of œsophagus. Fibrinous pleurisy.** (*Fig.* 444.)

L. McC., female, age 16, was admitted Oct. 2, 1918, under the care of Mr. Pringle, as a case of acute appendicitis. The patient was extremely ill, pulse 132, temperature 104·2°, respirations 44. The patient, who had previously been in good health, was seized with severe pain in the region of the umbilicus on Sept. 29. She vomited soon after, and this recurred several times. The abdomen was tense, rigid, and tender all over. Dullness was present in both flanks. Nothing unusual was made out by rectal examination. Lungs clear. The patient vomited twice after coming into the ward, and before her operation—which was done as soon as possible—about five ounces each time of a dark-brown, almost reddish, fluid. A small abscess was found at the appendix, and there was a generalized purulent peritonitis. The appendix was not removed. The abscess was drained, and a Keith's tube was passed to Douglas's pouch through a small suprapubic incision, a quantity of puriform fluid escaping through it. The patient died at 6.0 a.m. the following morning, twelve hours after admission; she vomited twice after the operation, each time bringing up a mouthful or two of the same dark-brown fluid that had been ejected before the operation.

P.M. Report (No. 9244), Oct. 4, 1918.—The body was that of a well-built, well-nourished girl. There was in very marked degree the dusky complexion which is seen in septic cases. There were two surgical wounds.

Thorax.—The heart showed some cloudy swelling. The lungs from the front were seen to be congested, but appeared generally normal. The left lung was found to be lightly adherent to the diaphragm, and on cutting the root and lifting up the lung a quantity of black fluid was seen coming from the œsophagus, and the tissues between that structure and the lung were pulpy and of dirty black colour. There was no definite digestion of the surface of the lung, but on the



FIG. 444.—Œsophagus from *Case* 4, softened and perforated in its lower portion, while its upper part shows suo-mucous hæmorrhages.

diaphragmatic surface there were some thin flakes of fibrin, and there were some subpleural hæmorrhages. The condition on the right side was similar to that on the left, there being a thin fibrinous exudate between the lung and the diaphragm, and between the back of the lower lobe and the posterior wall of the thorax. There were numerous subpleural hæmorrhages in the inner and diaphragmatic aspects of the lung. The œsophagus appeared as a black, ragged band ; and at three points, respectively about 2 in. and 3 in. above the diaphragm (*Fig.* 444), it was perforated and black fluid was escaping. The œsophagus, lower part of trachea, and stomach were removed *en masse*. The digested condition of the œsophagus stopped abruptly at the upper surface of the diaphragm. There was no pus above the diaphragm, and it appeared highly improbable that the fibrinous exudate in the pleural sacs was due to extension of the suppuration from the abdomen, the substance of the diaphragm and the connective tissue below it appearing quite normal.

Abdomen.—There was a general purulent peritonitis, the cause of which was gangrene of the appendix. The liver and kidneys showed marked cloudy swelling. The spleen was slightly enlarged, with soft full pulp. The stomach, which was examined along with the œsophagus, contained a small quantity of slaty-grey fluid quite different in character from the black fluid which was present in the œsophagus. There was very slight post-mortem digestion of the fundus of the stomach, with minute extravasation of blood into the mucous membrane ; otherwise it presented normal characters.

Sections were prepared from part of the left lung, where the surface was markedly digested, having been in contact with the œsophagus without interposition of the pleural membrane. The areolar tissue was necrotic, and showed no reaction. The surface of the lung in parts was also necrotic. This condition involved a superficial layer of at most two to three alveoli. Beneath this the alveoli were occupied by blood. Some of the necrotic alveoli seemed also to have contained blood. Deeper still the condition passed into œdema of the lung, with more or less of hæmorrhage. There was very little sign of reaction, but polymorphonuclear leucocytes were recognized in places in greater number than would be accounted for by the presence of blood. There was marked congestion.

A section was also prepared from the surface of the right lung where there was a fibrinous exudate. There was a good deal of degenerative change in the exudate, but its character was quite distinct. The cells were to a considerable extent mononuclear, with no great number of polymorphonuclear leucocytes, and there was swelling and proliferation of the endothelium of the pleura. The lung showed a condition similar to that already described. There could be no question as to the presence of vital reaction.

Case 5.—**Excision of gangrenous appendix. Advanced digestion of œsophagus. Subpleural hæmorrhages.**

D. T., age 19, blacksmith, was admitted into the wards of the Western Infirmary under the care of Sir Hector Cameron at 1.0 a.m. on March 17, 1909. Abdominal pain and rigidity, and marked tenderness on pressure. Some distention. Temperature 101·2°, pulse 120. At operation the appendix was found to be gangrenous. The abdomen was drained. Patient gradually got worse, and died at 11.45 p.m. the same night.

P.M. Report (No. 7895), March 19, 1909.—The body was that of an extremely well-built and well-nourished youth. Post-mortem lividity marked. There was a wound in the right inguinal region, with a gauze drain.

Thorax.—The heart was normal. The pleural sacs contained a small quantity of grumous dark slate-coloured fluid. The lungs were congested, and considerable areas of the inner aspects were of slate colour, and softened on the surface. Outside these areas there were numerous subpleural hæmorrhages and interstitial emphysema, i.e., gas-bubbles in the surface of the lung. Beyond this zone of emphysema there were a few small hæmorrhages. There was no fibrinous exudate, and no definite adhesion between the visceral and parietal pleuræ. The cause of this condition was found in digestion of the œsophagus, the lower two inches of which were almost completely destroyed. The condition extended considerably higher in gradually decreasing degree. The cardiac ring was not digested, and was retaining the gastric contents to all appearance perfectly. The stomach showed only a slight degree of superficial post-mortem digestion. In other respects it was healthy.

Abdomen.—There was a general peritonitis, with fibrinous exudate and a comparatively small amount of pus. The stump of the appendix was securely closed. There was no trace of adhesions about it. There was extreme cloudy swelling of the liver. The spleen was somewhat enlarged. Nothing else of note was found.

Case 6.—**Excision of perforated appendix. Hæmatemesis. Advanced digestion of the œsophagus. Subpleural hæmorrhages and emphysema.**

I. N., age 21, was admitted to the Royal Infirmary under the care of Mr. Rutherfurd on May 11, 1909, as a case of appendicitis. The appendix was removed on the same day. It was found to be perforated, and there was much pus in the iliac fossa and pelvic cavity. The abdomen was drained. On May 13 patient vomited brown material. On May 14 she was noticed to be 'jaundiced.' She died at 2.0 a.m. on May 15.

The opinion of the surgeon was that patient was doing well until the day before her death.

P.M. Report (No. 5970), May 15, 1909.—The body was that of a well-built, well-nourished girl.

Thorax.—The heart presented healthy characters. The right lung showed some hæmorrhagic spots in the pleura on the inner aspect, posteriorly. The left pleural cavity contained a quantity of turbid, slate-coloured fluid, and the gastric contents could be seen escaping into it from a perforation of the œsophagus just above the diaphragm. Practically the whole posterior and diaphragmatic surfaces of the lung were of a dark slate colour with reddish markings. The middle parts of this area were smooth, but the margins showed many gas-bubbles apparently underneath the pleura. The lung tissue underlying this area appeared to be unaffected.

Abdomen.—The field of operation appeared to be in a satisfactory condition. The liver showed extreme fatty change. The kidneys were the seat of interstitial nephritis, with cloudy swelling, and apparently fatty degeneration. The stomach was anæmic. It was ulcerated, and remarkably free from post-mortem digestion, which was recognizable only near the cardiac orifice and was quite superficial. The œsophagus, on the other hand, showed a very intense maceration, with separation of the longitudinal muscles, extending from the cardiac orifice three or four inches upwards. The wall had given way on both sides; but extravasation of contents had occurred only into the left pleural cavity, the right pleural cavity and the abdomen not being affected.

There was also digestion of the duodenum, commencing about half an inch beyond the pyloric orifice, and extending for about three inches downwards. Extravasation had taken place into the connective tissues behind the duodenum, and also below and to the right, but it was doubtful whether there had been any escape into the peritoneal cavity.

Case 7.—**Suture of perforated duodenal ulcer. Advanced digestion of œsophagus.**

J. McE., age 39, under the care of Mr. Rutherfurd. Took ill on June 10, 1914. Operation was performed on June 11, and a perforation of a duodenal ulcer was found. The perforation was sutured and the abdomen closed. The patient died on June 13. There were no distinctive symptoms.

P.M. Report (No. 7749), June 15, 1914.—The body was that of a big, rather fat subject. There was some peritonitis about the field of operation, but there had been no further leakage, and the condition generally appeared to be satisfactory. There was a small characteristic acute duodenal ulcer.

Thorax.—The heart was rather flabby and dilated. The right pleural cavity contained some clear serous fluid. The lungs showed hypostatic congestion and œdema. The left pleural cavity contained about 20 oz. of dirty green fluid with fat floating on it. The source of this was found to be the œsophagus, which was extensively digested, and perforated at two points. The changes in the œsophagus extended from immediately above the cardiac orifice to opposite the bifurcation of the trachea. The tissues were soft and ragged and of a dirty black colour. The surface of the lung was digested over a wide area, and the pleural membrane had completely disappeared, so that the surface consisted of collapsed-looking lung tissue.

Abdomen.—The stomach showed post-mortem digestion, limited to the fundus and posterior wall.

Case 8.—**Acute hepatitis? Hæmatemesis. Early digestion of the œsophagus.**

M. S., age 4½, was admitted to the Royal Infirmary under Dr. Jack on Sunday, Aug. 30, with a history of sudden development of vomiting of yellow coloured matter on the previous Wednesday. She complained of severe pain in her stomach. She became delirious on the Saturday. On the Sunday, the fifth day of illness, she vomited chocolate-coloured material. The stools were clay-coloured. Nothing further was made out after admission to hospital, where she died the following day.

P.M. Report (No. 7820).—The body was that of a fairly well-nourished child. There was marked hypostatic lividity, and general dusky coloration of the skin. This was not jaundice, but rather the coloration suggestive of intense toxic disease.

Thorax.—The heart appeared normal. The lungs showed some hypostatic congestion.

Abdomen.—The liver was considerably enlarged, and of a bright mottled red and yellow colour. In parts there was almost none of the red colour, so that it looked not unlike the liver of phosphorus or delayed chloroform poisoning. The kidneys also were pale and yellow, probably from fatty degeneration. The stomach contained a small quantity of dark-brown material suggestive of altered blood; there were no ulcerations or hæmorrhages or post-mortem digestion. The œsophagus showed marked digestion, which commenced immediately above the cardiac ring and extended up for about three inches. The muscular coat was distinctly affected, but there was no perforation. The contents of the duodenum showed distinct bile staining, but those of the lower part of the small intestine and colon were clay-coloured.

Microscopic examination of the liver showed advanced fatty change, and there was also fatty degeneration in the kidney.

Case 9.—**Pneumonia. Digestion and perforation of œsophagus. Hæmorrhages into the substance of œsophagus.**

D. L., age 13, was admitted to the Royal Infirmary under the care of Dr. Mackenzie Anderson on Oct. 3, 1914. He was extremely ill. Signs of lobar pneumonia in the lower lobe of the right lung were made out. He died, apparently from cardiac failure, on the third day of illness, two hours after admission to hospital.

P.M. Report (No. 7851), Oct. 5, 1914.—The body was that of a well-built, well-nourished, but very livid boy.

Thorax.—The heart showed slight hypertrophy of the right ventricle and some cloudy swelling. Both the lungs were adherent about the posterior part of the lower lobes. There was pneumonic consolidation of the posterior two-thirds or thereby of the right lower lobe, with marked congestion, and some hæmorrhage among the fibrous adhesions. Further out there was a very thin, fibrinous layer. The rest of this lung appeared healthy. In the left lung there were also hæmorrhages among fibrous adhesions over the inner part of the lower lobe. There was a small quantity of yellow serous fluid in the upper part of the sac, but Dr. Nora M. A. Allan, who made the post-mortem examination, was certain that there were no gastric contents. There was digestion of the surface of the lower lobe and lowest part of upper lobe over a considerable area. There was distinct congestion suggestive of vital reaction at several points, and some gas-bubbles in the fibrous tissue. The œsophagus was digested and perforated on the left lateral and anterior surfaces, and the tissues round about it seemed swollen and infiltrated with blood. There was old collapse and bronchiectasis of the lower lobe of the left lung, and marked recent œdema, possibly with some consolidation.

Abdomen.—The stomach contained a small quantity of turbid yellow material, suggestive of upper intestinal contents. The mucous membrane appeared thick, and there were a good many punctate hæmorrhages in it suggesting early post-mortem digestion. There was no breaking down. The cardiac orifice presented similar characters, but immediately above it there was advanced softening and breaking down involving all coats of the œsophagus, and there were a number of hæmorrhages into the œsophageal tissue which looked as if they must have occurred during life. This was noticed on the posterior wall, opposite to and rather above the perforation already described. The condition ceased about three inches above the cardiac ring. The liver and kidney showed marked cloudy swelling. The spleen seemed enlarged, soft with full pulp. There was a large, calcified mesenteric gland.

Case 10.—**Gallstones. Cholecystectomy. Fairly early digestion of œsophagus. Hæmorrhage into its wall.**

Mrs. I., age 46, was admitted to the Royal Infirmary on April 1, 1915, under the care of Mr. Rutherfurd. There was a history of acute illness of about seven days' duration. No jaundice. Some chronic bronchitis. The gall-bladder was excised on April 3. Found full of gall-stones, with purulent fluid and very hard walls. Patient collapsed on April 4, late in the evening, and died in early morning.

P.M. Report (No. 8029), April 6, 1915.—The body was that of a rather stout woman. There was slight lividity about face and neck. There was a closed operation wound in the right hypochondriac region.

Thorax.—The heart showed very advanced fatty infiltration, and diffuse fatty degeneration. Valves and vessels were apparently healthy. There were some old adhesions at the apex of the left lung. The œsophagus lying between the lungs was noticed to be of mottled dark-red colour, but there was no appearance of escape of its contents into either pleural sac. The posterior parts of the lower lobes of both lungs showed a very distinct and fairly general consolidation with intense congestion, and many subpleural hæmorrhages. There was no distinct digestion of the surface of either lung, but the areolar tissue between them and the œsophagus appeared a little softened and slightly infiltrated with blood. On the right side there was a distinct purulent condition. There was clearly pneumonia, and in parts it was distinctly of patchy character. It was more marked towards the inner aspect of the lung than towards the outer—that is to say, it was most marked in the neighbourhood of the œsophagus. The rest of the lungs were slightly emphysematous, and the bronchi contained much mucopurulent secretion.

Abdomen.—There was adhesion about the seat of operation, and a small quantity of bloody serous fluid welled out below the right margin of the liver. The liver showed advanced fatty change. The stump of the cystic duct was found apparently well secured. The stomach showed only slight post-mortem digestion, but immediately above the cardiac orifice there was marked softening of the œsophagus. The tissues were infiltrated with black altered blood and the muscular fibres separated, so that there must have been very nearly perforation on the right and posterior aspects. Nothing of note in the intestines was found. The spleen was somewhat enlarged, with full grey pulp. The kidneys showed some cloudy swelling.

Two microscopic sections of the œsophagus were made. One of these included the cardiac ring, and it showed advanced digestion of all the coats starting just above it. No evidence of reaction could be found, unless the following could possibly be interpreted in that way: the veins were very full of solid red clots, in the centre of one of which was a fairly bulky strand of fibrin—which suggests that there had been a clotting and a contraction followed by engorgement with fresh blood. The slightly digested part showed very superficial change, and no reaction.

Sections of the right lung showed advanced pneumonia of patchy type, more hæmorrhagic on the surface, with digestion of the pleura, but no reaction which could be related to that. The left lung showed less advanced patchy pneumonia.

Case 11.—**Cardiac valvular disease. Hæmatemesis. Early digestion of œsophagus.**

D. McR., age 22, warehouseman, was admitted to the Royal Infirmary under the care of Dr. W. R. Jack, as a case of cardiac disease, aortic and mitral, on Nov. 2, 1915. The abdomen

was tapped four times between Nov. 28 and Dec. 10 for ascites. On Jan. 18 he developed tonsillitis. On Jan. 26 he had a shivering which was the commencement of pneumonia. There was spitting of bright-red blood on Jan. 27. On the day of his death, which took place at 12.10 p.m. on Feb. 3, he was "spitting a large amount of blood; also vomiting a great deal of blood."

P.M. REPORT (No. 8346), Feb. 4, 1916.—The body presented the characteristic appearances of an advanced chronic cardiac valvular disease, being generally œdematous, livid, and slightly jaundiced.

Thorax.—The right lung was deeply congested, voluminous, and in the lower lobe there were a number of areas of early pneumonic consolidation. The lower lobe of the left lung was completely consolidated, being in a state of grey hepatization, and there was a thin fibrinous layer on parts of the surface. There were early pneumonic patches in the upper lobe. No infarction could be made out. The heart was enormously hypertrophied and dilated. There was old endocarditis of the mitral and aortic valves, apparently with both obstruction and incompetence.

Abdomen.—The liver, spleen, and kidneys showed pronounced venous congestion. The stomach was large, and contained a considerable quantity of slate-coloured fluid and numbers of grape-stones and portions of grapes. Venous congestion was not very marked, and while there were some quite recent hæmorrhages into the mucosa, there was no ulceration, nor evidence of old hæmorrhages. There was some post-mortem digestion towards the fundus. The orifice of the œsophagus was very much congested, and there was a small ulcer at one point, but connection with a vein could not be made out. Externally the œsophagus was extremely congested in its lower part, and the muscular tube stripped very cleanly from the connective tissues. About four inches up, this condition ceased and the appearance became practically normal. Internally the mucous membrane was deeply congested, and there were long streaks of blackening which looked like the result of hæmorrhage into the mucous coat. Higher up this tailed off into a brown discoloration resembling superficial necrosis, and about five inches from the cardia the tube became fairly normal in appearance. This condition seemed the most likely source of the hæmorrhage noted during life, and was regarded as ante-mortem digestion which happened to open a large superficial vein in the œsophagus.

Case 12.—**Puerperal eclampsia. Hæmatemesis. Early digestion of œsophagus.**

Mrs. R., age 28, IV-gravida, was admitted to the Glasgow Royal Maternity and Women's Hospital under the care of Dr. A. W. Russell on March 25, 1916, as a case of eclampsia. She was seven months pregnant. Her previous confinements had been normal. History of swelling of the legs and feet for some weeks previously was obtained. There were sixteen fits on the day of admission, and she became unconscious. On March 26 she was delivered of a macerated fœtus 3¼ lb. in weight. She remained persistently unconscious, and died on March 30.

At the post-mortem examination Dr. Teacher was informd that there had been coffee-ground vomiting, but the exact time before death had not been recorded.

P.M. REPORT.—The body was that of a fairly well-nourished but anæmic woman. There were marks of subcutaneous saline injections under the mammæ.

Thorax.—In the heart there were a number of subendocardial hæmorrhages, apparently quite recent. The myocardium showed some cloudy swelling, but no hæmorrhages. The lungs showed marked hypostatic congestion and œdema. At the left base there was an area of slightly more definite consolidation about the size of a marble, apparently an infarction.

Abdomen.—There were numerous pale and rather indistinct subcapsular hæmorrhages in the liver, principally over the right lobe. In section, there were no distinct hæmorrhages, but there was very advanced cloudy swelling, with fatty change and fairly marked venous congestion, and a few areas were seen of slightly larger size which may have been hæmorrhagic rather than simple congestion. The condition was characteristic of eclampsia, but not very marked. The spleen was considerably enlarged, congested, fairly firm, with abundant dark-grey pulp. The kidneys showed slight evidence of old nephritis, the surface being very slightly granular, and there were some depressed areas like arteriosclerotic patches (the aorta and main vessels, however, showed no arteriosclerosis). The cortex was very broad and yellow, apparently from advanced cloudy swelling and fatty change. No hæmorrhagic areas or infarcts. The stomach contained a quantity of slaty-grey fluid. The œsophagus appeared wide, and on opening was found to contain black fluid, and the lower four inches of it showed commencing digestion. From the clinical history of coffee-ground vomiting this (in the absence of lesion in the stomach) was probably *intra vitam* in origin, and the cause of the coffee-ground vomiting.

Case 13.—**Puerperal eclampsia. Vomiting of brown material and pain in chest. Advanced digestion of œsophagus. Hæmorrhages under pleuræ. Widespread digestion of surfaces of lungs.**

M. McS. was admitted to the Maternity Hospital on Sept. 16, 1918, under the care of Prof. Munro Kerr. She had had two fits before admission, and two occurred after admission. The usual treatment was given. She vomited some green material, but appeared to be improving on Sept. 17. On Sept. 19 she complained of soreness over the right lung and pain between the sternum and shoulders. On Sept. 20 labour commenced in the evening, and delivery was completed by forceps about 1.0 a.m. on Sept. 21. The child was macerated. On the same day she vomited brownish material at 8.0 a.m. She suffered from a "sore cough," and again vomited brown material at 3.0 p.m. She died at 9.40 p.m. on Sept. 22.

P.M. Report.—The body was that of a strongly built, well-nourished young woman.

Thorax.—The heart showed some cloudy swelling, otherwise it was healthy. There was much hæmorrhage about the surface of both lungs under the pleura, distributed principally up the back and inner aspect of both lungs, not only at the base but also to a considerable extent near the apex. The right lung showed a somewhat patchy, but well-developed, pneumonia. The lower four inches or thereby of the œsophagus was reduced to shreds, and the connective tissue around it was in a gelatinous condition, and black from infiltration with altered blood. There was also distinct digestion of the portions of both lungs adjacent to the œsophagus. The digestion was less marked, but still present, above the level of the bifurcation of the trachea. It did not extend beyond the cardiac orifice, and there was no digestion of the stomach and no erosion or ulceration. The contents of the stomach were blackish from the presence of altered blood.

Abdomen.—The liver was large and of mottled-red and yellow colour, and there was very advanced cloudy swelling. There were none of the hæmorrhages which are seen in many cases of eclampsia. The spleen was slightly enlarged and soft. The kidneys showed well-marked cloudy swelling and some masking of the markings and congestion suggestive of subacute nephritis.

Case 14.—**Fracture of femur. Abdominal section. Hæmatemesis. Early digestion of œsophagus.**

J. S., age 52, was admitted to the Royal Infirmary on Nov. 17, 1918, under the care of Mr. Rutherfurd, with a history of having fallen from the footplate of a locomotive, and sustained injury to the left hip. There was found to be a fracture of the neck of the left femur. A few days after admission he complained of abdominal pain, which was relieved by an enema. The stools were suggestive of blood being present, but examination gave a negative result. On the evening of Nov. 27, patient vomited a considerable quantity of material containing stale blood, and the abdomen became distended and rather tense, with dullness in both flanks. The abdomen was opened the following morning, but no free fluid was found, and nothing was found in the intestines or stomach. The abdominal pain continued, but without further vomiting. The abdomen remained quite soft until the patient died.

P.M. Report (No. 9299), Nov. 30, 1918.—The body was that of a small, rather poorly nourished man. There was marked eversion of the left foot, the hip was fixed, and there was a good deal of swelling around it.

Thorax.—The lungs were rather atrophic, and there was an early bronchopneumonia in the upper lobe of the right lung. The heart was large and powerful, there being distinct hypertrophy of the left ventricle. There was some atheroma of the coronary arteries. No valvular lesion.

Abdomen.—The liver showed some cloudy swelling. The spleen was rather large and soft, and there were old adhesions over it. The kidneys were about normal in size, and did not show definite interstitial change, but the arteries were somewhat thickened. There was no pancreatitis. On proceeding to remove the stomach, the œsophagus was found to be very large, being dilated immediately above the cardiac ring to a diameter of nearly an inch and a half. This condition extended up for about four inches, and then the tube returned gradually to the normal size. There was no perforation, but the exterior of the tube was blackened in patches over the dilated part. This was most noticeable on the left side, and there was one bulge which suggested yielding of the wall. The œsophagus was found to contain a large quantity of black fluid, which clearly was altered blood. The interior of the dilated portion was obviously in a digested condition. Most of the mucous coat was softened, and a good deal of it was dissolved, and at the point corresponding to the bulge there was what looked like ulceration into a vein. The stomach was full of black turbid fluid. There was no ulceration, and digestion could not be made out. The whole organ felt rather soft. The intestines were irregularly contracted. There was no obstruction.

There was a fracture of the neck of the femur close to the head, and impaction of the neck into the trochanters. The head was loose. There was no sign of healing.

Case 15.—**Excision of gangrenous appendix. Hæmatemesis. Early digestion of œsophagus.**

A. M., age about 20, was admitted under the care of Mr. Rutherfurd on Nov. 29, 1918. Two days before admission patient had pain in the right side of the abdomen, accompanied by sickness and vomiting. On admission, the abdomen was quite lax, with slight tenderness over McBurney's point. On Nov. 30 the abdomen was opened. Appendix found gangrenous in distal third. Appendicectomy performed and abdomen closed. A few hours after operation patient became very sick, and during the night vomited a quantity of dark coffee-coloured fluid. Died on evening of Dec. 1, twenty-eight hours after operation.

P.M. Report (No. 9301), Dec. 2, 1918.—The body was that of a very well-built and very well-nourished young woman. There was a closed operation wound in the right iliac region. Hypostasis was very marked.

Thorax.—The heart showed advanced cloudy swelling of the muscle; it was otherwise normal. The lungs showed marked hypostatic congestion and very slight œdema. In view of the history, the œsophagus was cleared, and was found to be dilated immediately above the diaphragm, and at one point on the lateral wall about an inch and a half above the diaphragm, and rather to the left side, there was some black colour and a slight tendency to local bulging. On opening, the tube was found to contain quantities of thin black fluid. The inner surface was extensively but superficially digested, and at a point corresponding with the bulging above mentioned, there was a little area which looked like an ulceration into a vein. It was, however, not found possible to

pass a fine probe into the vessel. The digestion extended from immediately above the cardiac ring to within about two inches of the glottis. There was no hæmorrhage into the walls of the œsophagus, the dark appearance apparently having been due to the black contents showing through the thinnest part of the wall.

Abdomen.—The stomach contained quantities of similar black fluid. There was no ulceration at any point, and no punctiform hæmorrhages. The fundus felt rather softer and was more relaxed than the pyloric end, there being apparently very slight digestion, but it did not amount to breaking down of the mucous membrane. The liver and kidneys showed some cloudy swelling. The spleen was rather large, but without marked fullness of the pulp. There was no general peritonitis. The region of operation was well shut off by fibrinous adhesions. There were a few ounces of thick fluid in the neighbourhood of the stump and in the pelvic cavity. The condition looked one from which the patient might have recovered.

DISCUSSION.

Before proceeding to discuss the evidence that the digestion of the œsophagus is a process which had occurred during life, it must be admitted that in all probability the digestion continues after death, and that some of the appearances described may be due to this. On the other hand, these post-mortem changes would have the effect of destroying the indications of vital reaction, such as the formation of fibrin in the pleural sacs, and of obscuring small hæmorrhages into the tissues of the œsophagus. This may well have occurred in some of the cases which showed very advanced destruction of the œsophagus and adjacent structures. Moreover, *Cases* 14 and 15, in which the changes were not advanced, might on this account have been passed over as post-mortem in nature but for the clinical observation of coffee-ground vomiting.

Perhaps the most important of all the records is that of M. B. (*Case* 1—J. H. P.). The œsophagus from this patient exhibited (*Fig.* 443) numerous submucous and intramural hæmorrhages of varying extent, many of them comparatively large; and while for the most part the mucous membrane over them is intact, a superficial disintegration of the membrane has taken place over some of them, resulting in the development of more or less widespread 'erosions.' We regard this case as showing an early stage of the condition, remarkably free from post-mortem change. In addition, there is a very definite ring of ulceration round the entire circumference of the cardiac extremity of the gullet, ending abruptly in a very sharply-cut margin at the junction of the œsophageal with the gastric mucous membrane, and becoming less marked the further it recedes from the stomach.

It is to be noted that in all cases this sharply-defined ulceration of the mucous membrane has been observed at the very termination of the œsophagus. In fact, the lower part of the gullet has always appeared to have suffered more severely than the upper; and when perforation has occurred, it has always been found low down in the tube. Possibly the constriction of the gullet by the diaphragm is responsible for this ring of ulceration; for it would appear that the compression exerted by the diaphragm on the œsophagus is very tight, as it has been remarkable how empty the stomach has been of blood in nearly all the cases we have examined.

Almost as important as *Case* 1 is *Case* 4 (J. H. P.). In the specimen from this case (*Fig.* 444) there is evidence of submucous hæmorrhages in the upper part of the tube not unlike those seen in *Case* 1.

If the hæmorrhages, which would undoubtedly predispose to erosion and perforation of the walls of the œsophagus, occur during life, as we believe, the hæmatemesis can be explained by the erosion of the mucous membrane over and around them. The chief fact in favour of these being the result of a process commencing *intra vitam* is that they are real intramural hæmorrhages and not post-mortem stainings.

We particularly draw attention to the fact that in *Case* 1 (J. H. P.) the patient complained of a retrosternal pain, for this is highly characteristic of œsophageal irritation—e.g., by a foreign body caught low down in the gullet. Nothing suggestive of this was observed in any of the other cases except *Case* 14 (puerperal eclampsia—Dr. Munro Kerr), but then they were mostly much more rapid in their course than these two.

The second fact of importance in *Case* 4 (J. H. P.) is that in the left pleural cavity evidence of the reaction of the tissues to the irritant in their immediate neighbourhood

was observed in the form of a fibrinous exudate on the pleural surface, and inflammatory reaction in the superficial alveoli of the lung adjacent to the œsophagus. In this case the œsophagus was perforated, but the extravasation had not extended into the pleural sac. It may quite well have happened in several of the cases in which this had taken place, that any fibrin, which might have formed, had been digested ; but in several cases the hæmorrhages into the lungs, and the small widespread subpleural ecchymoses, remained as evidence of the vital nature of the condition.

We see no improbability in the suggestion that perforation and leakage from the œsophagus may actually be the final cause of death from shock. Nor is it impossible in our opinion that a condition such as is shown in *Fig.* 443 might be recovered from, if there were no lethal disease present at the same time. A far worse local condition of the œsophagus must have been induced in many instances where caustic fluids have been swallowed and in which recovery still occurred.

What we believe takes place in these cases is that in the course of a toxic disease gastric juice escapes into the œsophagus and may not be expelled, but, lying in the lumen, is able to start and establish a process of digestion of the already devitalized coats of the gullet. We believe that the œsophagus from *Case* 1 exemplifies an early stage of this process ; and it is to be observed that in *Case* 4 the patient vomited blood before the operation was commenced, which is at least suggestive of the presence at that time of a state analogous to that found in *Case* 1. It appears to us that any operation, with the resulting shock, and the general anæsthetic if one has been employed, must only be looked on as predisposing conditions acting as devitalizing agencies.

This view is supported by consideration of those cases in which no operation had been performed. These were cases either of acute infections—two pneumonias and one anthrax ; or intense toxic conditions—two puerperal eclampsias and one obscure condition in which acute degenerative change in the liver was the principal feature. We hold that these cases substantiate our contention that digestion of the œsophagus is a process which is liable to develop in any class of case in which the vitality of the tissues is greatly reduced, and in which vomiting of active gastric juice happens also to occur.

SUMMARY AND CONCLUSIONS.

Post-operative vomiting of black material or hæmatemesis is a symptom of great importance to the practical surgeon. In some cases the cause of these symptoms appears to be digestion of the œsophagus. This condition may vary in different cases from superficial erosion of the interior of the œsophagus to perforation or widespread destruction of the tube and damage to adjacent structures. The vital nature of the condition is shown by the presence of hæmorrhages into the œsophageal wall, lungs, and pleuræ ; while, in one case at least, inflammatory reaction was observed in the lungs and pleural sacs.

The vomiting of black material or actual hæmatemesis was observed in eleven out of the above fifteen examples of digestion of the œsophagus found at post-mortem examination. In six of the cases no operation had been performed, but these were all of a severe infective or toxic nature. In contrast with the state of the œsophagus, there was usually little or no digestion of the stomach.

In conclusion, we submit that digestion of the œsophagus may occur during life, and that as a result blood may be vomited.

That this digestion may take place in any disease in which great lowering of vitality occurs.

That ante-mortem digestion of the œsophagus is one cause of post-operative hæmatemesis.

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BONES SHOWING THE EFFECTS OF GUNSHOT INJURIES,

IN THE ARMY MEDICAL COLLECTION NOW ON EXHIBITION IN THE MUSEUM OF THE ROYAL COLLEGE OF SURGEONS OF ENGLAND.

By Professor ARTHUR KEITH, F.R.S., Conservator of the Museum, and Captain MORTON E. HALL, C.A.M.C.

By the end of 1918, over 4000 specimens had been forwarded to the Museum of the Royal College of Surgeons of England by the Medical Services of the British Imperial Forces, to illustrate the nature of the wounds and diseases which are met with under conditions of modern warfare. As the specimens arrived, they were numbered, registered, and suitably stored, every effort being made to obtain and keep a full history of each specimen. Of these specimens, 1155 have been prepared, mounted, described, and placed on exhibition in the Museum of the College, 688 of them as 'wet' preparations to show the damaged condition of the soft tissues, and 467 as macerated preparations to show the effects of gunshot injuries on the skeletal parts of the body. The 'wet' preparations are being investigated, prepared, described, and constantly added to by Professor S. G. Shattock and Mr. Cecil Beadles. Here we propose to deal with the macerated series only, in which the various parts of the body are represented as follows :—

Injuries affecting the	calvaria or cranium	109
,, ,,	face	37
,, ,,	spine	32
,, ,,	pelvis and sacrum	36
,, ,,	hip-joint	5
,, ,,	femur	76
,, ,,	knee-joint	14
,, ,,	leg	49
,, ,,	ankle-joint	9
,, ,,	foot	7
,, ,,	sternum	1
,, ,,	ribs	3
,, ,,	scapula	24
,, ,,	clavicle	14
,, ,,	shoulder-joint	3
,, ,,	humerus	27
,, ,,	elbow-joint	5
,, ,,	forearm	13
,, ,,	carpus and hand	3
Total number of macerated specimens		467

How the Collection was Formed.—Before proceeding to describe the macerated specimens and draw from them the lessons they teach, it will be well to give a short account of the circumstances under which the Army Medical Collection has been brought together.

In November 1914, a Committee was formed, under the presidency of the Director-General of the Army Medical Services—then Sir Alfred Keogh—to compile a Medical History of the War. One of the aims of this Committee was to collect from casualty clearing stations and military hospitals examples of wounds and diseases, and to examine and preserve such specimens, so that, when the Medical History came to be compiled, the recorders would have access to an ample supply of first-hand material on which to base

their descriptions and conclusions. It was also realized by the Committee that such specimens, if suitably preserved, would constitute instructive documents which might be profitably examined and studied, not only by military surgeons of to-day, but also by their successors for many generations to come.

In the earlier months of the War every endeavour had to be concentrated on the immediate medical requirements of the Army, and hence it was not until May, 1915, that measures were taken to put the scheme of the Committee into operation. Sir Walter Fletcher, who had undertaken the secretaryship of the Medical History Committee in addition to his onerous post as secretary to the Medical Research Committee, approached the Council of the Royal College of Surgeons on behalf of the Army Council, to obtain its assistance in the formation of an Army Medical Collection. The Council of the College responded at once by placing its museum staff and workrooms at the disposal of the Army Council.

Although circular memoranda were issued to medical officers, detailing the aims of the Committee and the methods to be observed in selecting, preserving, and dispatching specimens, the results were meagre, and remained so until the commencement of 1916, when the Director-General of Medical Services in France—then Sir Arthur Sloggett—placed Lieutenant-Colonel T. R. Elliott in charge of this particular service. Specimens then arrived in numbers ; they were selected examples, preserved by the latest and best methods. The co-operation was enlisted of the younger pathologists and surgeons attached to clearing stations and hospitals in France—Captain Herbert Henry, Captain T. G. Shore, Major G. Richardson, Captain Adrian Stokes, Lieutenant-Colonel E. M. Cowell, Major S. W. McNee, Captain A. Petrie, and many others. At a later date the Canadian and Australian Medical Corps organized similar collecting services ; so that although the greater part of the collection now in the Museum of the Royal College of Surgeons represents the effort of the Royal Army Medical Corps, yet large sections of it have been gathered by the Colonial sister services. These sections will be set up as Army Medical Collections in Canada and Australia.

There was no intention at the outset of forming a separate series of macerated specimens. It is true that almost from the commencement specimens of this kind were received from France, particularly from Major G. Richardson, who adopted a special process of his own for cleansing bones, and has enriched the collection by some of the most instructive specimens to be found in it. The movement which led to the formation of a macerated series came from Cambridge University. When Lieutenant-Colonel Sir John Bland-Sutton was appointed by the Director-General, in the spring of 1917, to stimulate and organize the collection of specimens from home sources, he found that a collection of macerated specimens, showing excellent workmanship, had been gathered in the Pathological Museum of the University of Cambridge. The material from which the specimens had been prepared was obtained from No. 1 Eastern General Hospital, under the command of Lieutenant-Colonel Joseph Griffiths, and represented lesions sustained by soldiers during the opening years of the war—lesions of bones in all stages of repair and disruption. They were the work of Sergeant F. A. Izzard, who had applied to them a simple and expeditious method of maceration he had elaborated during many years of service as assistant in the Pathological Department of the University. Sergeant Izzard has printed and distributed a leaflet giving an account of his method, which, in our opinion, yields far better results than any other ; it is expeditious, and preserves unharmed the most delicate structural features of bones, be they diseased or healthy.

Description of Method used by Sergeant F. A. Izzard.

A preparation from the operating theatre or post-mortem room is placed in an earthenware jar or pot of suitable size filled with water at a temperature of 80° F., and at this temperature the water is maintained day and night for four days. On the fifth day the water is poured off, and the jar again filled up with fresh water at the same temperature (80°). Every fifth day this operation is repeated. By the tenth, fifteenth, or twentieth day it will be found that the soft tissues will have separated from the bones and left them exposed. Sergeant Izzard is of opinion that the greater the amount of soft tissues left on the bones, the better and quicker does the process of macerating proceed ; there is, he says, no greater error than in seeking to expedite the process

by clearing off all the soft tissues before placing the part in the macerating pot. All that should be done then is to make incisions in the soft parts, merely skin and fascia deep, so that the macerating fluid may have free access to the underlying parts. The process is one of bacterial digestion. A certain degree of stench accompanies the process. When it is seen that the bones are exposed and separated from the soft tissues, they are taken from the macerating pot and scalded with two or three kettles of boiling water, which will clean all excess of filth from the bones. The bones are then scrubbed with soap in boiling water, a tooth brush being used for this purpose, the ordinary nail brush being much too coarse. When thus scrubbed, the bones are again scalded in boiling water to remove soap and any other matter which may still cling to them. They are then dried in the sun or by the fire. When dried, they are examined to see if they are free from grease; if grease is present, they must be placed in benzoline for two days, the benzoline being given free access to the medullary cavity by drilling minute holes if necessary. When removed from the benzoline retort the bones are usually dry and of a good colour; but if whiteness is desired, this can be obtained by placing them for several days in a 10 per cent solution of peroxide of hydrogen —distilled water being used in the solution. This bleaching solution may serve for several relays of specimens before becoming inert.

We have given Sergeant Izzard's method in some detail because of the excellence of the specimens which it has yielded in his hands. The Cambridge specimens which were thus prepared became the nucleus of the Army Medical Collection of Macerated Specimens at the Royal College of Surgeons. They were sixty in number: but unfortunately in several instances it was impossible to obtain a history of the case from which they had been derived. Sergeant Izzard went to France in March, 1917, and, working under Captain T. G. Shore, prepared a particularly valuable series of specimens. For over a year he has continued this work for the Army Collection at the Museum of the Royal College of Surgeons.

In mounting preparations showing the explosive or disruptive forms of gunshot injuries, no attempt has been made to represent the scatter or disruption of fragments; in every instance the fragments have been again fitted together, so that in the mounted macerated specimen we have a representation of the *lines* along which the skull or bone-shaft ruptured when struck by the missile.

Having thus given an account of the formation of the Macerated Collection, we shall now proceed to describe the types of injury which are met with in the various bones of the body, commencing with the cranium or brain-containing part of the skull.

INJURIES TO THE CRANIAL PART OF THE SKULL.

As already mentioned, there are 109 preparations of cranial injury. In Section I of this article we describe what may be called the type specimens; in Section II we illustrate variants of the type specimens.

Section I.—TYPE SPECIMENS.

We have divided these injuries into three main groups: (1) *Contused*: (2) *Penetrating*; (3) *Perforating* (through-and-through).

Group 1.—Contused Injuries of the Cranium.

The term *contused* has been used to include a variety of injuries in which the projectile did not enter the cranial cavity. In this group are included injuries due to a projectile striking the skull a direct blow but with insufficient momentum to carry it through the cranial wall, or those where an area of skull is crushed by a missile—such as a fragment of shell or spent bullet. This group also includes injuries resulting from a tangential or glancing blow from a projectile—such projectiles usually having considerable momentum. In the collection there are 67 specimens showing contused injury. We have divided such injuries into four classes: (*a*) *Internal table only*; (*b*) *External table only*; (*c*) *External table slightly, very marked internal table*; (*d*) *Grooved and massive, involving both tables over an extensive area.* Each of the classes has again been classified on an anatomical basis according to the bone affected, as frontal, parietal, occipital, etc.

a. **Contused Injuries without Depression of External Cranial Table but with Fracture of Inner Table.**—There are 5 specimens in the War Office Collection showing the above type of injury, 4 of the parietal bone and 1 of the occipital bone. The reason why this type of injury is so sparsely represented is probably owing to the low mortality which attends its infliction. The external table, being unbroken, prevents the entrance of infection. Also, when recognized by the surgeon, this type of injury has responded most readily to radical operative treatment, and for this reason a description of the specimens will be of value.

Two specimens, Nos. 1.201 and 1.202, have been selected to illustrate this type of injury (*Figs.* 445*a*, 445*b*, and 446*a*, 446*b*).

No. 1.201 shows an irregular oval area (29 × 18 mm.) on the external table of the left parietal bone, near its postero-medial angle, where the missile struck. It is slightly discoloured, but there is no fracture or depression. The internal view shows an area of the internal table, irregularly oval in shape (28 × 25 mm.), which is semi-detached from the diploe opposite the area of impact. There are two fragments. The semi-detached area involves the terminal branches of the middle meningeal vessels of the left

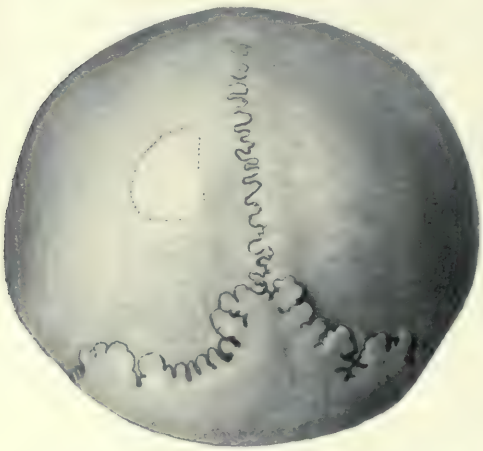


FIG. 445*a*.—No. 1.201. External view, showing the area of left parietal bone struck by the projectile. No fracture or fissuring is observed at point of injury.

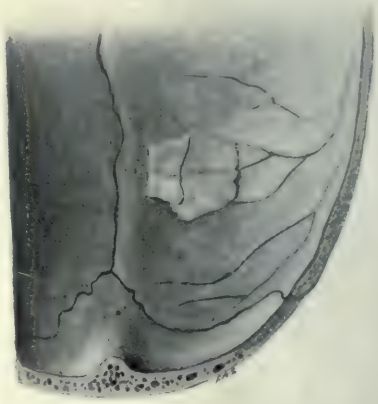


FIG. 445*b*.—No 1.201. View of the internal surface of calvaria, showing the extent of fracture, with two detached fragments.

side. The soldier was wounded on April 12, 1917. On admission to hospital he had a gutter scalp wound near the left parietal eminence, and was in a comatose condition. The scalp wound became rapidly septic, and he died April 22, ten days after injury. At the autopsy a considerable subdural hæmorrhage was found at the site of fracture, with pulping of the cerebral cortex. No note was made of the condition of the dura. In this case it is probable that the missile did not actually strike the bone, the fracture being produced by the lateral displacement of the soft tissues which lay in its track.

Specimen No. 1.202 shows a contused injury just above the eminence of the left parietal bone. At the point of impact of the missile there is a circular area of the external table, 30 mm. in diameter, which is discoloured, but which shows no depression or fracture. From the posterior margin of this area a fissure extends across the vertex to the right temporal line. The internal table is depressed—the depressed area showing two fissures, but no separation of fragments. A fissure, corresponding to that seen on the external surface, extends across the vertex, but does not extend into either fissure at the site of fracture. Unfortunately we have been unable to obtain a clinical history of this specimen.

Specimen No. 1.2023 demonstrates a more severe type of injury of the inner table. The external surface of the calvaria, near the antero-medial angle of the right parietal

bone, presents an oval area 30 × 20 mm. on the outer table, which is bruised, but not fractured or depressed. The inner surface shows complete fracture and detachment of the inner table, over a pear-shaped area 20 × 30 mm. Five fragments were found embedded deep in the substance of the left hemisphere There was a gutter scalp wound, 8 cm. long, over the site of fracture. This specimen was presented to the collection by Dr. Harvey Cushing, of the American Medical Service, and has been fully described by him in this journal.*

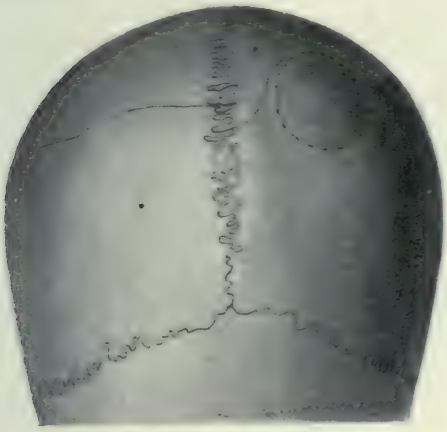


FIG. 446a.—No. 1.202. External surface of calvaria, showing the circular discoloured area of impact over the left parietal bone.

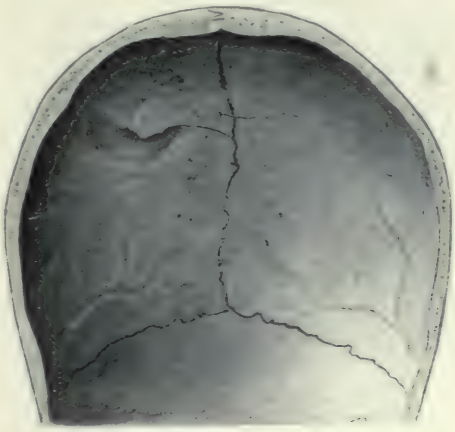


FIG. 446b.—No. 1.202. View of the internal surface of the calvaria, showing a depressed fracture of the inner table opposite the discoloured area.

We do not propose to discuss the mechanism underlying this type of fracture; we simply point out that the internal table is more brittle and less supported than the external table. The internal table therefore suffers most, and develops a depressed fracture; not unusually, as in specimen No. 1.2023, its fragments are driven deeply into the substance of the brain. In specimen No. 1.201, the injury to the internal table is local; while in specimen No. 1.202, fissures extend a considerable distance from the point of impact.

b. **Contused Injuries of External Table, without Injury to Internal Table.**—There are 3 specimens in the Collection showing the above class of injury; 2 are of the frontal bone, and 1 of the parietal bone. Each of the specimens shows a more severe injury of another class. Specimen No. 1.131 may be taken as a type. There is a contused wound of the frontal bone above the right supercilliary eminence, with an aperture 7 × 5 mm. in the external table, opening into the upper limit of the frontal sinus; the inner table is splintered and detached. Above the right frontal eminence a thin fragment of metal is lodged in the external table, but with no injury to the inner table. The soldier was wounded on June 7, 1917. He suddenly became unconscious on June 19, and died the same day. An abscess of the frontal lobe was found at the autopsy, as a sequel to the major injury. In the three specimens in the collection with injury to the external table, the injury has been the result of small shell-fragments with sharp margins, and evidently with insufficient momentum to penetrate the inner table.

c. **Contused Injuries in which the Outer Table shows Slight Injury and the Inner Table Marked Comminution.**—There are 16 specimens in the Collection showing the above variety of injuries, of which 5 are of the frontal bone, 11 of the parietal, and 1 of the occipital. In this type of injury, in contrast to the lesions we have grouped in class (*a*), there is fracture of the outer table, the fragments of which are driven inwards

* *Brit. Jour. Surg.* 1918, April, p. 567.

and act as an aid in the destruction of the inner table. In the majority of the specimens, the fragments of the fractured inner table have been driven into the brain substance, producing a laceration of the dura.

Specimen No. 1.204 is an example of this injury (*Figs.* 447*a*, 447*b*). There is a small depressed fracture in the upper part of the Rolandic area of the left parietal eminence,

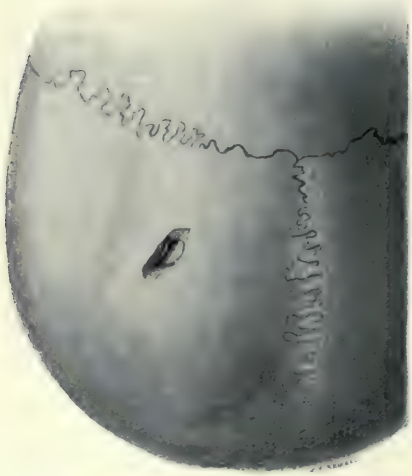


FIG. 447*a*. No. 1.204. External surface of calvaria, showing depressed fracture of the outer table of the left parietal bone. There is no fissuring.

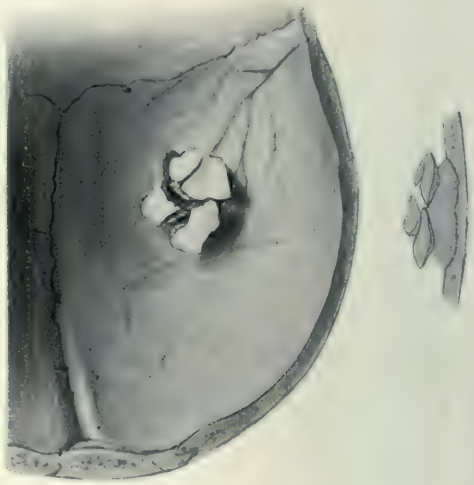


FIG. 447*b*.—No. 1.204. Showing the fracture of the inner table, with several detached fragments. The marginal diagram represents a transverse section through the bone at the point of injury.

caused by a fragment of shell. There is no fissuring of the outer table, which is merely crushed into the diploe, but the inner table is splintered into several fragments which are detached. The history of this case is not known.

Specimen No. 1.2024 shows a more marked injury to the outer table (*Fig.* 448*a*). There is a radiating fissure of the right parietal bone near the inferior margin. An irregular area 33 × 9 mm. is splintered into five fragments, three of which are depressed

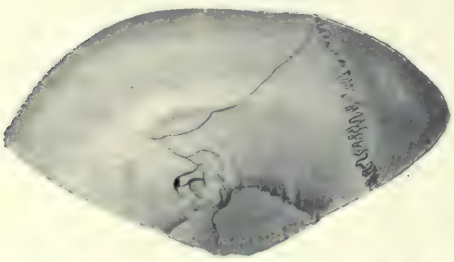


FIG. 448*a*.—No. 1.2024. External surface of the right parietal bone, showing a depressed fracture with fissuring.

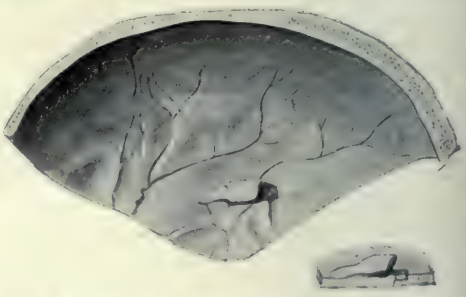


FIG. 448*b*.—No. 1.2024. View of internal surface, showing injury of inner table. The fragments are depressed, and one fragment is missing. The underlying meningeal vessels were ruptured.

and driven into the diploe. From this area a fissure extends to the coronal suture near the antero-medial angle. A second fissure extends downwards to the base. The inner table under the depressed area of the outer table is comminuted, with depression of the fragments, one of which was entirely detached and driven into the underlying cortex. The patient was wounded Aug. 18, 1917. The wound of the scalp was excised, and no

fracture could be felt ; there was no evidence of cerebral injury. There were also wounds of the right arm and shoulder. He became comatose, and died Aug. 22, four days after injury. The posterior branch of the meningeal artery was found to have been lacerated by the detached fragment of the inner table (*Fig.* 448*b*). There was no sepsis of the cortical tissue.

Specimen No. 1.2656 (*Figs.* 449*a*, 449*b*) is a portion of left parietal bone which was removed by a trephining operation to relieve a paralysis of the right arm. The operation was followed by gas-bacillus infection of the brain, and death two days later. There is an oblong aperture 30 × 10 mm. in the specimen, in which the bone fragments —of which at least two have necrosed—have been replaced *in situ*. It will be noted that the area of the inner table affected, 43 × 33 mm., is considerably greater than that of the outer table. The fragments of the inner table have been completely detached

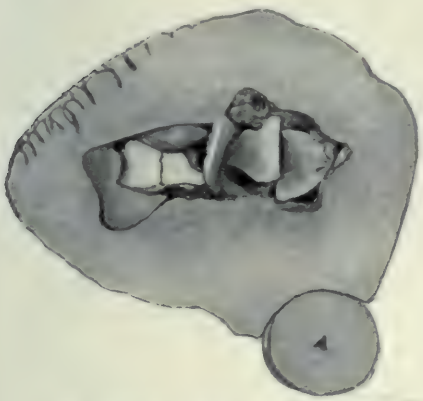


FIG. 449*a*.—No. 1.2656. External surface of a portion of left parietal bone removed by trephining operation to relieve a paralysis of the right arm. It shows an oblong aperture, in which the fragments have been replaced *in situ*.

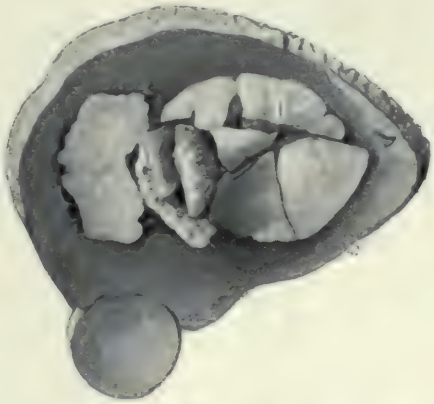


FIG. 449*b*.—No. 1.2656. A view of the internal surface of the same specimen, showing the fragments of bone *in situ*. The area of inner table involved is extensive in comparison with that of the outer table.

d. **Contused Injuries of the Grooved and Massive Variety.**—The Collection contains 44 specimens of this type of injury, 10 of the frontal bone, 23 of the parietal, 7 of the temporal, and 4 of the occipital. This type of injury, the commonest in the cranial series, comprises fractures of a major character in which the skull shows a massive crushing lesion, often the result of a blow from a large shell-fragment striking with diminished momentum. In this class we also include the so-called 'grooved' type of injury resulting from a glancing or tangential blow by a rifle bullet of high velocity. This classification has been decided upon largely because we have found that the fractures and fissuring produced by both kinds of missile are similar in character.

Specimen No. 1.021 (*Fig.* 450) is an excellent example of massive crushing injury of the calvaria. There is extensive comminution of the left parietal bone, with numerous gaping fissures extending forwards, backwards, and across the remaining portion of the calvaria. The soldier was admitted on March 11, 1917, to No. 2 Canadian Casualty Clearing Station, in an unconscious condition. The date of injury is not known. On admission he had a linear scalp wound, two and a half inches long, over the posterior portion of the left parietal bone, to the left of the sagittal plane. The wound was excised and some bone fragments were removed. He died March 16, but no record of the autopsy is available.

Specimen No. 2.444 shows a less extensive crushing injury of the calvaria (*Fig.* 451*a*, 451*b*). There is a large aperture in the frontal bone 62 × 30 mm., irregular in outline, just above the lateral angle of the left orbit. The wound was enlarged by the surgeon. From

the medial margin of the aperture a wide fissure extends across the body of the frontal bone, with branches, one to a point above the lateral angle of the right eye, another towards the coronal suture, while a third enters the right orbit. Numerous fissures

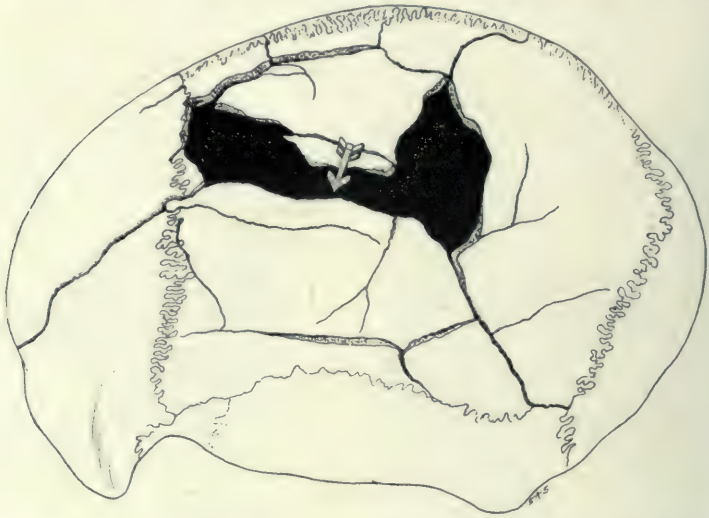


FIG. 450.—No. 1.021. Lateral view of calvaria, showing extensive comminution and fracture of left parietal bone. The arrow indicates the direction of projectile. The fragments in the region of the blow have been entirely separated, and some have been removed by operation. The main area of fracture is 9 × 50 mm., and numerous fissures extend from the margins in every direction, some of them gaping widely.

extend from the primary wound towards the base. Apparently a second missile has entered the inner wall of the left orbit. The floors of the anterior and middle cranial fossæ are fissured and shattered to a marked extent (*Fig.* 451*b*). Both maxillary bones



FIG. 451*a*.—No. 2.444. Left lateral view of skull, showing aperture in frontal bone with fissures extending across the body of the bone. The shattering of the wall of the orbit is also shown.

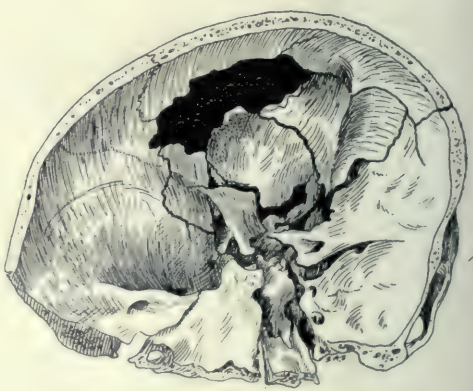


FIG. 451*b*.—No. 2.444. Internal surface of the calvaria, showing aperture in frontal bone, with extensive fracturing of left great wing of sphenoid and of floor of middle and anterior cranial fossæ.

are fractured. The bones of the face are remarkably thin. The soldier was wounded on June 11, 1917; the wound was explored and bony fragments were removed eight days later, and he died June 21. The autopsy findings are not known.

Specimen No. 1.28 (*Figs.* 452*a*, 452*b*) shows a type of lesion due to a tangential blow from a shell fragment. There is a depressed linear fracture situated on the posterior inferior aspect of the right parietal eminence. The missile apparently entered at the anterior end of the fissure, driving inwards the two tables of the calvaria. The aperture thus produced is oval in shape, and measured 40 × 9 mm. The external margin at the anterior half of the aperture is depressed, while in the posterior half the external margin

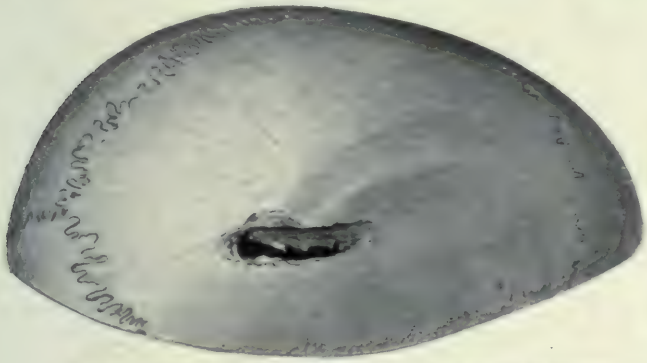


FIG. 452*a*.—No. 1.28. External surface of calvaria, showing an aperture in right parietal bone caused by a tangential blow, with depressed fragment in its floor. Note the marginal chipping at the posterior end of the aperture.

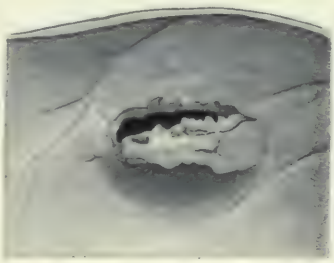


FIG. 452*b*.—No. 1.28. Internal view of the right parietal bone, showing the fragments fixed in position by healing.

has been carried away by the missile. The fragments of the calvaria are attached to one another and to the main portion of the bone at the posterior end of the aperture, and have become fixed in position by healing. On the cerebral aspect of the injured area there is evidence of a pachymeningitis. There is no fissuring of the calvaria except of the finest character, which is confined to the inner table at the posterior end of the aperture. No history of this specimen could be obtained.

Specimen No. 1.25 (*Fig.* 453) shows a similar lesion to the last, but more extensive in destruction results. There is a gunshot wound of the left parietal bone, causing an irregular gap 65 × 25 mm. The missile, probably a bullet, entered at the medial end of the aperture and emerged at its lateral end. There is undercutting of the medial margin at the point of impact, with a depressed fragment *in situ*. The lateral, posterior, and anterior margins are overcut, showing an external bevelling. From the gap four wide fissures radiate towards the base, two from each end, and it will be noted that they are arranged as in the so-called 'butterfly' type of fracture. The fissures are partially filled with new bone deposit, and the margins of the aperture also show signs of healing. No history of this case was obtained.

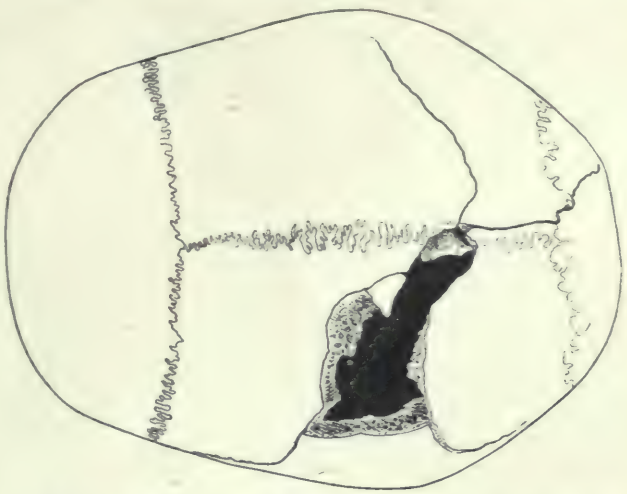


FIG. 453.—No. 1.25. Showing the effects of a tangential blow. The missile entered at the medial end of the aperture—almost on the sagittal suture—and carried away fragments from the lateral end.

Group 2.—Penetrating Injuries of the Cranial Cavity.

The Collection contains 33 specimens of penetrating wounds—injuries in which the missile becomes lodged within the cranial cavity. Penetrating injuries have been subdivided into two groups: (*a*) *Simple—those with no secondary injury from the same projectile*; (*b*) *Those with secondary injury, in which the projectile, having passed through one wall of the cranium, produced a secondary injury of another portion of the cranium.*

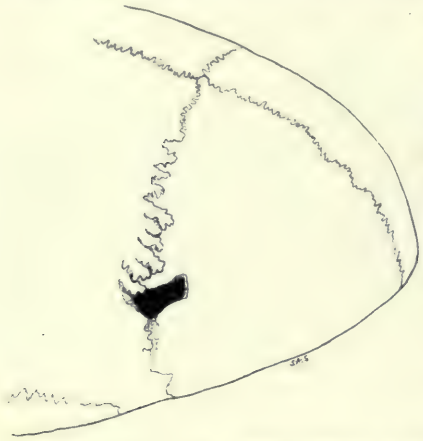


Fig. 454.—No. 1.143. External surface of the calvaria, showing a simple punctured wound of the right lateral surface of the frontal bone at the coronal suture. There are no marginal fissures. A median frontal suture is present.

a. **Simple Penetrating Injuries of the Cranium.**—The simple injuries naturally fall into two groups, one in which a clean aperture in the wall is formed without fissuring; and a second where fissuring and explosive effects are seen. There are 14 specimens which show simple penetrating injury with no fissuring of the surrounding bone, 3 being of the frontal, 4 of the parietal, 5 of the temporal, and 2 of the occipital bone.

Specimen No. 1.143 (*Fig.* 454) is an example of this class. There is a rectangular aperture in the right lateral portion of the frontal bone, just on the coronal suture. The injury was evidently produced by a shell fragment which penetrated the brain. The aperture is clean-cut, and there is no fissuring. No history of this case is obtainable.

There are 12 specimens of simple penetrating injuries which show fissuring of the area of penetration, and in many cases other disruptive or explosive effects. Specimen No. 1.2115 (*Fig.* 455) is a cranium with a gunshot

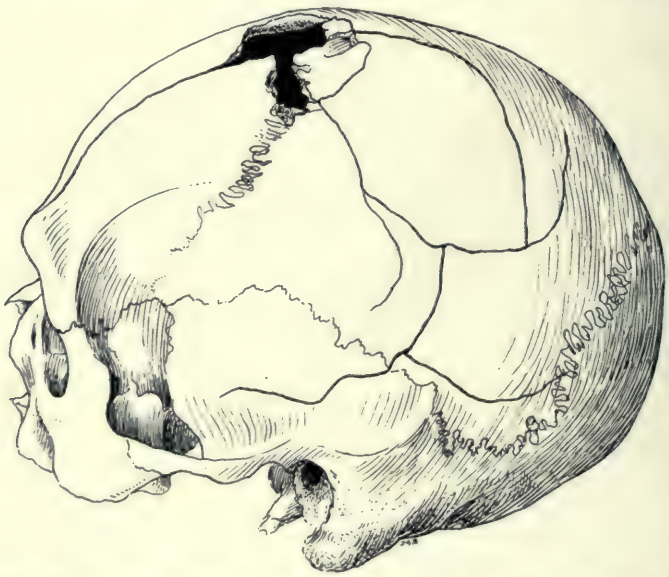


Fig. 455.—No. 1.2115. Cranium showing a penetrating injury of the vertex. Two fragments, forming the posterior margin of the aperture, are depressed.

fracture in the bregmatic region of the vertex, producing an irregular aperture 27 × 27 mm., with extensive splintering of the left parietal and of the frontal bones. The

fracture of the frontal extends to, and involves, the inner wall of the right orbit and right maxillary bone. Two bone fragments forming the posterior margin of the aperture are depressed. An extensive inverted Y fissure passes backwards and downwards to the squamous portion of the left temporal bone. The soldier was wounded Nov. 27, 1918, and died in a casualty clearing station thirty hours later. At autopsy, a shell fragment (copper driving band), 1 × 1 × ½ cm. in size, and pieces of indriven bone, were found embedded in the cortex of the left hemisphere. The surrounding brain substance was markedly lacerated, and there was extensive subdural hæmorrhage over the left parietal, frontal, and temporal lobes.

b. **Penetrating Injuries of the Calvaria with Secondary Injury to another portion of the Cranium.**—This is a small set of 5 specimens, 4 of which show partial penetration of the opposite wall of the cranium, and 1 of which shows an internal ricochet of the missile on the opposite wall of the cranium. Specimen No. 1.165 (*Fig.* 456) shows an extensive right frontal and left parietal type of injury caused by a piece of shell-casing. The projectile entered above the right frontal eminence, producing a crescent-shaped aperture, 35 × 10 mm., with a single fissure descending towards the right orbit. The missile became arrested in the aperture of exit in the left parietal bone near the ventral end of the coronal suture. This aperture is circular, 25 mm. in diameter. The specimen shows a fragment of bone *in situ*, with the missile fixed in the aperture. The soldier was wounded on May 12, 1917. He developed a cerebral hernia, with aphasia, and facial convulsions. He died May 27. Meningitis with cerebral abscess was found at autopsy.

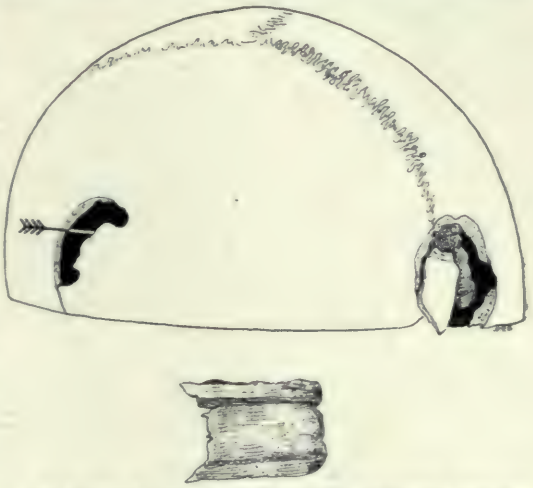


FIG. 456.—No. 1.165. External surface of the calvaria, showing crescent-shaped aperture of entrance, and an aperture in left parietal bone at the ventral end of the coronal suture, over the right frontal eminence, in which can be seen the piece of shell-casing and a loose bone fragment. The piece of shell-casing is represented below, half natural size.

Specimen No. 1.134 (*Figs.* 457*a*, 457*b*) is a calvaria with a large shell fragment,

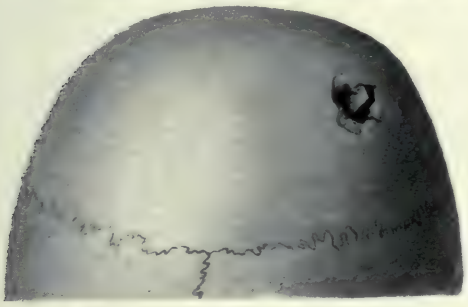


FIG. 457*a*.—No. 1.134. External surface of calvaria, showing an internal punctured wound of the right side of the frontal bone, with the missile, a shell fragment, lodged in the aperture.

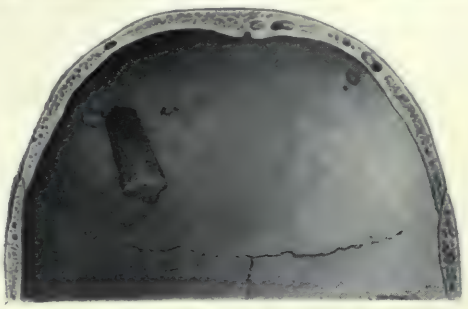


FIG. 457*b*.—No. 1.134. Internal surface of calvaria, showing the portion of the missile within the interior of the cranium.

43 × 10 mm., lodged in the right half of the frontal bone. The missile grazed the right shoulder, and entered the base of the skull from behind the right ear. It passed through the brain, and, perforating the frontal bone, became lodged in the aperture. About one

quarter of the missile extends beyond the margin of the aperture, which is 8 mm. in diameter, and shows external marginal bevelling but no fissuring. The soldier was wounded on Sept. 6, 1917, and died twenty-four hours later. The portion of the base of the cranium showing the aperture of extrance of the missile has not been preserved.

Group 3.—Perforating Injuries of the Cranium.

A perforating injury may be defined as that type in which the missile passes through two walls of the cranium and produces a wound of entrance and a wound of exit. In the Collection there are 22 specimens showing perforating injury. We have employed the following nomenclature to indicate their nature: bifrontal, biparietal, frontoparietal, fronto-occipital, parietofrontal, etc., the first-named bone indicating the site of the entrance aperture, the second that of the aperture of exit. The lesions were distributed as follows:—

Bifrontal		5
Frontoparietal		1
Palato-occipital		1
Occipitofrontal		1
Parietofrontal		2
Parieto-orbital		1
Biparietal		6
Temporoparietal		1
Bi-occipital		1
Occipitoparietal		0
Temporo-occipital		1
Temporo-orbital		2
	Total ..	22

Specimen No. 1.234 (*Fig.* 458) is an example of parieto-frontal injury. The missile, a bullet, entered near the posterior superior angle of the left parietal bone, and emerged below the left frontal eminence. The aperture of entrance is circular, 8 mm. in diameter, with marginal fracture of the outer table. The aperture of exit is irregular in shape, 28 × 12 mm., and surrounded by an oval area which is extensively fractured, and demarcated by a fissure. A gaping fissure commencing at the aperture of entrance ends in the oval fissure surrounding the area of exit. A linear fissure crosses the forehead for some distance from the wound of exit. No history of this case was obtained.



Fig. 458.—No. 1.234. Lateral view of calvaria, showing the apertures of entrance and exit in a case of bullet wound. An extensive oval area of fracturing surrounds the aperture of exit, and a gaping fissure joins the two apertures.

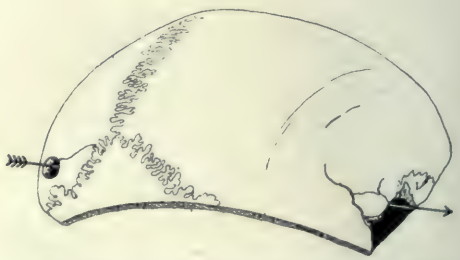


Fig. 459.—No. 1.252. Posterolateral view of calvaria, showing a biparietal or parietotemporoparietal perforating injury. The aperture of entrance is sharply punched.

Specimen No. 1.252 (*Fig.* 459) differs from the specimens already described, in that the wound of entrance, near the posterior superior angle of the left parietal bone, is a clean-cut puncture, 8 mm. in diameter, with no shattering of the surrounding bone, and only one short fissure extending inwards and forwards from its anterior margin. The aperture of exit in the right parietosquamosal region is large, and irregular in shape. There is

considerable shattering of the margins of aperture, with numerous radiating fissures. No history of this case is available.

Specimen No. 1.1605 (*Fig.* 460) shows the effects of a bifrontal perforating injury. The missile, apparently a bullet, entered in front of and near the mid-point of the right coronal suture, and emerged above the left angular process of the frontal bone. The frontal bone is thick, 8–9 mm., and the bullet, entering and emerging at a tangent to the plane of the bone, has caused rugged apertures at its points of entrance and emergence. There is an extensive series of fissures : one joins the apertures of entrance and exit, while the others radiate out from these apertures—particularly that of emergence. From each aperture a fissure descends on the forehead, and involves the orbital plates. One spreads backwards on the roof of the skull from each aperture. A fissure passing backwards on the left side above the level of the zygoma tends to separate the basal from the upper part of the skull. An isolated fissure crosses the floor of the left cerebellar fossa. No notes could be obtained of this specimen.



FIG. 460.—No. 1.1605. Cranium, showing extensive fracturing following a bifrontal perforating injury caused by a bullet.

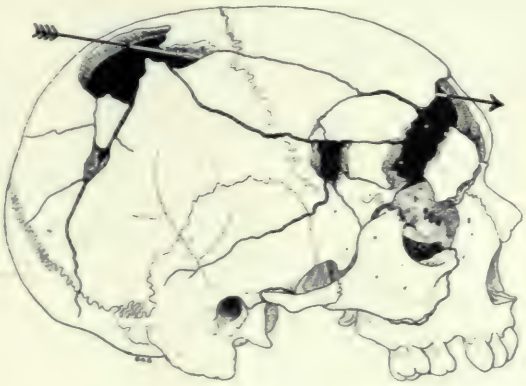


FIG. 461.—No. 1.235. Lateral view of calvaria, showing an extensive perforating parietofrontal injury.

Specimen No. 1.235 (*Fig.* 461) shows a very severe parietofrontal injury. The missile, probably a fragment of shell, entered above the right parietal eminence, and emerged on the forehead above the root of the nose. The apertures of entrance and exit are large, irregular, and connected by a series of fissures. From the aperture of entrance, fissures extend downwards to the lambdoid suture on the right side. There is marked comminution of the frontal bone surrounding the aperture of exit, with loss of the orbital plate of the frontal bone. Numerous fissures extend into the base from the aperture. The soldier was wounded on Nov. 16, 1917, and died four hours after admission to hospital. At autopsy, the whole of the right frontal lobe was found to be pulped.

Specimen No. 1.8231 (*Fig.* 462) shows a temporo-occipital perforating injury. The missile, probably a bullet, entered 15 mm. above the right auditory meatus, and made an exit in the supra-occipital region, 35 mm. above and to the left of the external occipital protuberance, and therefore involved the pole of the left cerebral hemisphere. The soldier, a German, was brought into No. 3 General Hospital on Sept. 7, 1918, deeply unconscious. The wound of entrance was explored and widened by operation (the aperture in the skull now measures 40 × 37 mm.) ; diffluent brain, soaked with greenish pus, escaped. The wound of exit was also explored, and the loose pieces of bone (now replaced

in the specimen, and indicated by stippling) were removed. The patient died soon after the operation. The specimen illustrates the 'explosive effects' which attend complete penetration of the skull, the occipital sutures in this case being wrenched open, besides producing fissures above and below the track of the missile.



FIG. 462.—No. 1.8231. Posterolateral view of skull, in which the occipital sutures have been wrenched open by a perforating tempor-occipital wound. The fragments shown by stippling were found loose, but have been replaced. There has been an explosive force which has caused extensive fissuring of the cranial chamber.

A study of specimens showing through-and-through perforating injuries of the calvaria indicates several points of marked interest. The aperture of entrance is smaller than the aperture of exit. Also the latter shows, as a rule, more marked fracturing of the surrounding bone. The apertures of entrance and exit, no matter how widely separated, are usually connected by a fissure, which is often gaping.

SPECIMENS IN WHICH A TREPHINING OR DECOMPRESSION OPERATION HAS BEEN PERFORMED.

There are 26 specimens in the War Office Collection in which an operation of the above kind has been performed.

Specimen No. 1.1783 (*Fig.* 463) is part of a calvaria showing a trephined, irregular aperture, 30 × 30 mm., in the frontal bone above and to the right of the right frontal eminence. The superior margin is circular, produced by a trephine drill, while the inferior margin has apparently been enlarged by the use of bone forceps. From the aperture a fissure crosses the coronal suture and, 25 mm. beyond that suture, divides into two diverging limbs. Another fissure descends towards the right orbit. The clinical history of this case is not obtainable.

Specimen No. 1.176 (*Fig.* 464) illustrates in a remarkable manner the extent of bone which may be damaged in massive contused injuries, and the radical nature of the resection which may be undertaken by the surgeon in its treatment. There is a hole in the frontal bone measuring 100 × 100 mm., representing the major portion of the body of the bone, and extending from the supra-orbital margin to the bregma. Apparently the frontal bone was struck by a fragment of shell. The soldier was wounded on April 3,

918, and a wide decompression operation was performed three days later. The frontal bone was badly shattered, with a large extradural clot, and bone fragments were removed, producing the aperture described above. He died the next day.

Two specimens described under previous headings, No. 2.444 (*Figs.* 451*a*, 451*b*) and No. 1.1832 (*Fig.* 462), are from cases in which a trephine operation had been done. In specimen No. 1.85 (*Fig.* 467) also it would seem that such an operation had been carried out. *Figs.* 449*a*, 449*b* also show large areas removed by trephining.

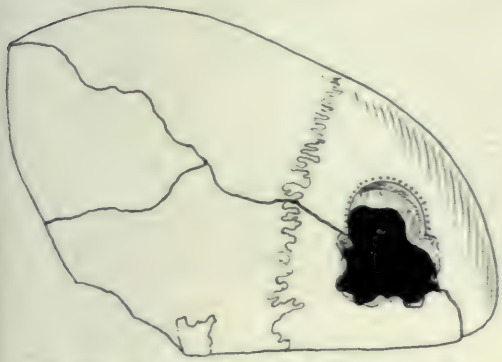


FIG. 463.—No. 1.1783. Showing a trephine aperture of the right frontal bone.

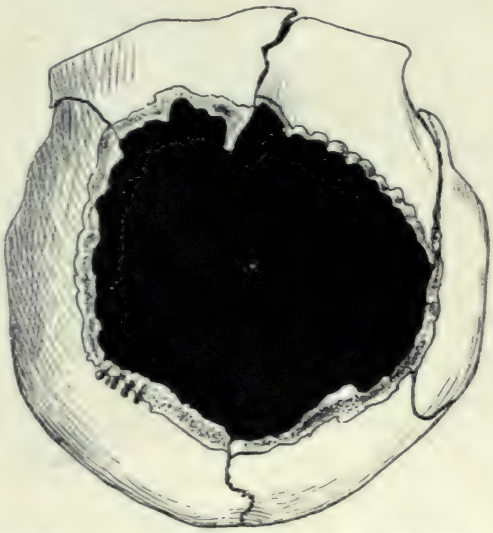


FIG. 464.—No. 1.176. Calvaria, showing almost the whole of the tabular part of the frontal bone removed by operation.

SPECIMENS OF CRANIA SHOWING VARIOUS REPARATIVE PROCESSES.

In the War Office Collection 16 specimens show evidence of various stages of healing. In two of these a definite history is available in which the injury had occurred one year before death.

Specimen No. 1.22 (*Fig.* 465) is the calvaria of a soldier showing the extent of the healing process a year after infliction of the wound. There is a perforating frontoparietal injury. The aperture of entrance is circular, 4 cm. in diameter, and lies partly in the frontal bone and partly in the left parietal bone, with the equator along the line of the coronal suture. It has been enlarged, and its posterior margin shows a narrow crescentic-shaped sequestrum entirely separated. The lateral and anterior margins are smooth and rounded by absorption. The medial margin is irregular, moth-eaten in appearance, and along the coronal suture, medially for about 2 cm., there is an area of the frontal bone showing granulation excavation. A second sequestrum

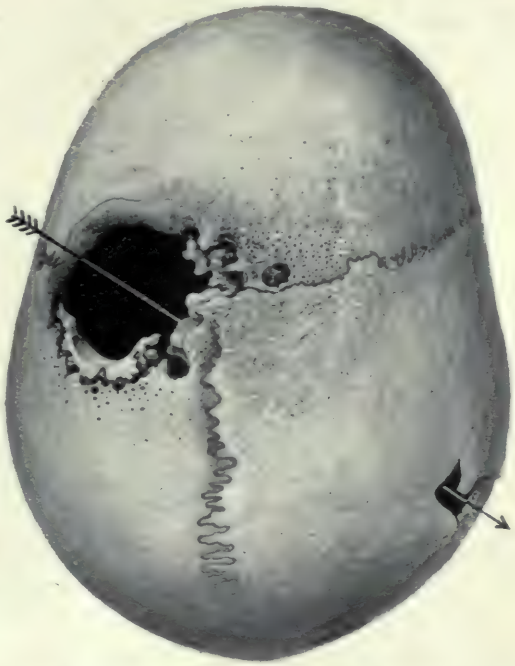


FIG. 465.—No. 1.22. Calvaria, showing the condition of a frontoparietal gunshot wound a year after infliction. Marginal sequestra are shown at the aperture of entrance, a result of chronic infection and suppuration.

lies against this margin in front of the sagittal suture, but separated from the surrounding bone. The surface of the external table of the surrounding areas of the calvaria is

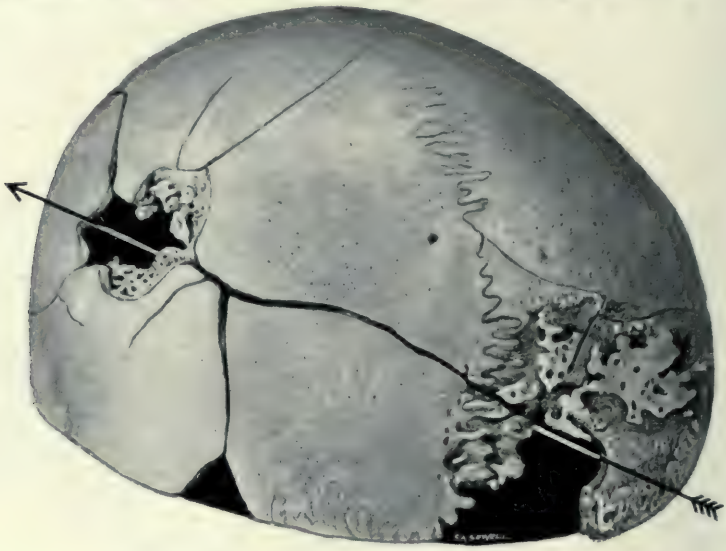


FIG. 466.—No. 1.251. Calvaria, showing early attempt at repair, particularly about the aperture of entrance. The arrow indicates the direction of the missile.

roughened, and fine callus points can be seen. The aperture of exit lies at the right parietal eminence. It is irregular in shape (17 × 33 mm.), and from it radiate three

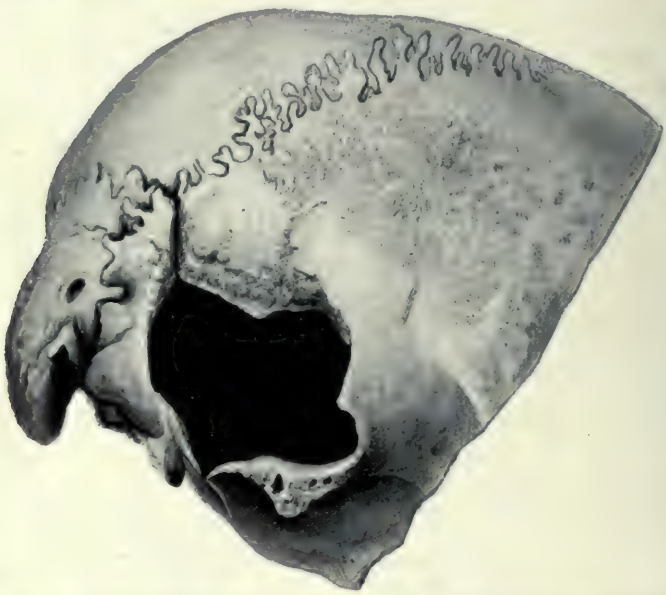


FIG. 467.—No. 1.85. Left occipital region of the skull, showing a large aperture with healed margin.

fissures which, although still clearly indicated, have been closed by bone deposition. The margins of the aperture of exit are smooth and thinned out, and a fragment has become

healed to the anterior margin. No clinical history of this case is available, other than that the injury occurred one year before the date of death.

Specimen No. 1.251 (*Fig.* 466) is that of an oblique biparietal gunshot wound. The aperture of entrance is situated near the posterosuperior angle of the right parietal bone; the aperture of exit below the left parietal eminence. The openings are connected by a gaping fissure, and from the aperture of exit numerous fissures radiate. One, widely open, passes to the left orbit; another into the temporal fossa; and a third towards the sagittal suture. The areas of bone between these fissures are somewhat elevated, indicating the 'explosive' effects of a perforating wound. The area of bone surrounding the aperture of entrance shows superficial exfoliation, the cortex having a moth-eaten appearance, due apparently to pyogenic erosion following elevation of the periosteum. The external margin of the aperture of exit is splintered, and part has been carried away. The exposed diploe is broken down and eroded.

Specimen No. 1.85 (*Fig.* 467) shows the process of healing completed. There is an oval aperture in the nuchal part of the occipital bone, 35 × 23 mm. in diameter, evidently caused by a gunshot wound received several months before death. The edges of the aperture are everted, smooth, and have been thinned out and rounded by absorption, no callus having been laid down. A short wide fissure, 2 cm. long, extends downwards from the aperture. The clinical history of this case could not be obtained.

Specimen No. 1.1605 (*Figs.* 468*a*, 468*b*) shows a bifrontal injury of the cranium, with an extensive series of fissures. The particularly interesting feature of this specimen is that it represents a completely healed depressed fracture of the right parietal bone. The area of depression measures 60 × 50 mm., and in extent and appearance suggests that it may

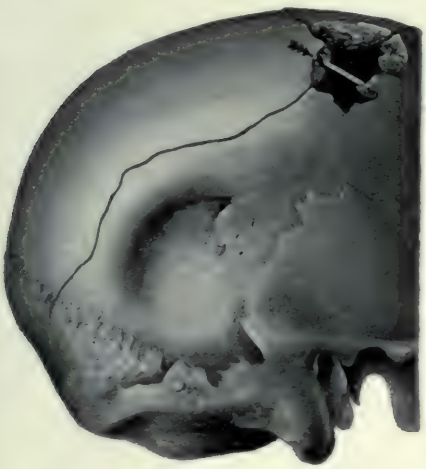


FIG. 468*a*.—No. 1.1605. External surface of calvaria, presenting the entrance aperture of a recent and fatal bifrontal injury, and a crescentic depressed area near the postero-inferior angle of the right parietal bone, the result of an old and healed depressed fracture.

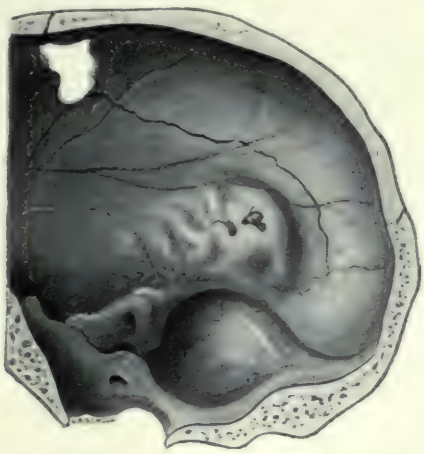


FIG. 468*b*.—No. 1.1605. Internal surface of same specimen, showing the condition of the depressed area. It lay over the posterior ends of the first and second temporal convolutions. The man was passed for general service.

have been caused by a severe accident—such as a kick from a horse. We estimate that the bone was driven inwards to a depth of 4 mm. On the inner aspect of the skull is seen a correspondingly raised area lying over the posterior or occipital ends of the first and second temporal convolutions. Although we have not ascertained either the manner or time of the accident which produced this unrelieved depressed fracture, there is no doubt that the functional result was good, for the man was passed for general service, and died when taking part in arduous fighting. The line of fracture is almost obliterated by bony union; only at certain points can it be traced by the presence of a series of vascular

foramina. The severity of the injury, the completeness of the recovery, and the obliteration of the line of fracture by bony union, make this specimen worthy of being placed on record.

A study of the specimens in the Collection showing a healing process brings out certain interesting features. It is not possible to enter into a discussion of the various views held concerning new bone formation and the repair of cranial injuries. One school has emphasized the importance of the periosteum in bone repair, and another the value of cancellous bone. In these specimens the separation of dead bone fragments and areas of infected bone by a process of sequestration can be readily traced, but in every case the amount of callus formation is scanty. In older specimens, fragments are cemented in place by internal callus. Gaping fissures become filled and obliterated. These points would serve to show that evidently, in the cranial bones at least, the cancellous bone is the only part capable of producing callus. To a limited extent this is due to the small area of cancellous tissue present. In old apertures one finds a process of absorption going on at the margins. They become thinned out and smoothed ; but none of the specimens n the collection show any attempt to bridge over the defect, even after an interval of a year. It is of interest to note that the trephine may so injure the bony margin of the aperture that the marginal area dies and is separated before the aperture undergoes a fibrous closure.

Section II.—ATYPICAL INJURIES OF THE CRANIUM.

In the War Office Collection there are specimens which illustrate the accidents as well as the wounds of warfare. One of the most remarkable of these accident specimens is No. 1.901, the skull depicted in *Figs.* 469*a*, *b*, *c*, and *d*. A soldier, while felling timber in France, had the misfortune to be caught by a falling trunk, by which his head was crushed. He was already dead when brought into No. 9 General Hospital, with blood escaping from his ears, nostrils, and mouth. The brain was found to be lacerated, and



FIG. 469*a*.—No. 1.901. Right lateral aspect of skull, showing a series of fissures in the right fronto-sphenoidal region, extending into the regions of the orbit, nose, and cheek—the result of a crushing accident.

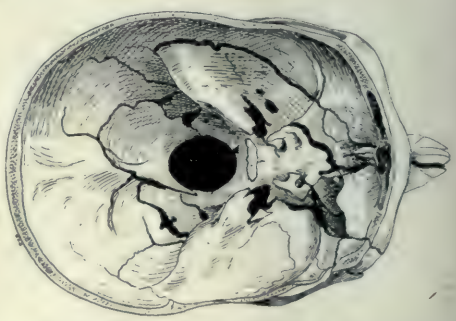


FIG. 469*b*.—No. 1.901. The base of the specimen depicted in *Fig.* 469*a*, showing a series of longitudinal fissures extending along the interior of the cranial floor.

the seat of extensive hæmorrhages, particularly on its basal aspect. The skull gives a vivid representation of the results of a crushing accident—one which tends to flatten the head from side to side. We note that the base of the skull has suffered most ; *Figs.* 469*b* and *d* show a complex of fractural lines, chiefly arranged in an anteroposterior direction, showing that the base of the skull is less able to withstand a crushing force —acting from side to side—than is the vertex or calvarial region, which in this case has escaped with minor damage. The temporal bones, forming solid triangular wedges, have been forced into the base, the thinner bone in the floor of the cerebellar fossa suffering

the greatest amount of damage. The crushing force was applied, apparently, in the region of the left mastoid, while the region of the right forehead and cheek became the chief fulcrum or region of resistance. As may be seen in *Fig.* 469*a*, the disrupting force has fallen on the right fronto-malar region, with the result that the malar and the adjoining part of the frontal bone have been driven inwards, tending to separate these parts from the rest of the skull. The right coronal suture has sprung open in part (*Fig.* 469*a*); so has the spheno-malar suture. The manner in which a lateral compressing force affects the face is shown with a diagrammatic distinctness in *Fig.* 469*c*. The malar bones have been driven towards each other, and have crushed the thin-walled maxillary supports interposed between them. The inter-orbital, infra-orbital, and nasal regions have been extensively fissured.

We requested Mr. Sewell to give particular pains to the palate of the specimen shown in *Fig.* 469*d*—not only to show the lines of fracture, but to show the contracted condition of the palate, which may be noted in fully 50 per cent of our soldiers. Such a condition is never seen in British skulls until the eighteenth century. Not only is the palate narrow, and high vaulted, but there is a lack of strength in the bones of the face, and often of the whole skull, as if there had been a defective deposition of bone during the age of body growth.



FIG. 469*c*.—No. 1.901. Facial aspect of the skull shown in *Fig.* 469*a*. The parts of the face interposed between the malar bones have been crushed by a compressing force acting from side to side.

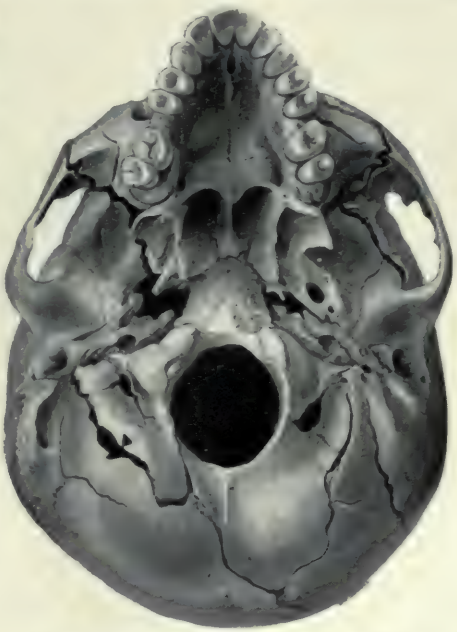


FIG. 469*d*.—No. 1.901. The outer basal aspect of the skull shown in *Fig.* 469*a*, showing the lines of fracture resulting from a compressing force. The palate shows a condition to be seen in 50 per cent of British soldiers.

In *Fig.* 470 we reproduce a series of sketches taken from specimen No. 1.253. The specimen itself is represented by the central drawing in the figure. The interior of that part of a skull which is formed by the upper part of the occipital bone and hinder part of the parietal is there depicted; the arrow shows the course of a shrapnel ball which has pierced above and behind the left ear, and, after traversing the brain, has come to rest beneath the scalp on the right side of the head. It is clear, from the fact that the ball had not sufficient momentum to escape from the soft parts which covered the right side of the head, that in making this through-and-through wound it had already lost its maximum velocity, yet it has drilled very clean holes in the bone. The apertures of entrance on both sides of the skull (*a*, *c*) are cleanly-cut round holes, (*c*) being slightly larger than (*a*), while the apertures of exit show external bevelling, which affects the internal table in the one case (*b*) and the external table in the other (*d*). The degree of destructive bevelling is greater in (*d*) than in (*b*), but it is plain that this result is not due to a difference in the texture of

the tables, but to a decrease in the velocity of the ball. The missile shows no appreciable flattening. The subject of this perforating (through-and-through) wound was a gunner, who died three hours after the infliction of the wound. There was no 'explosive' effect apparent in either skull or brain. (Compare with the case of shrapnel-ball fracture shown in *Fig.* 478.)

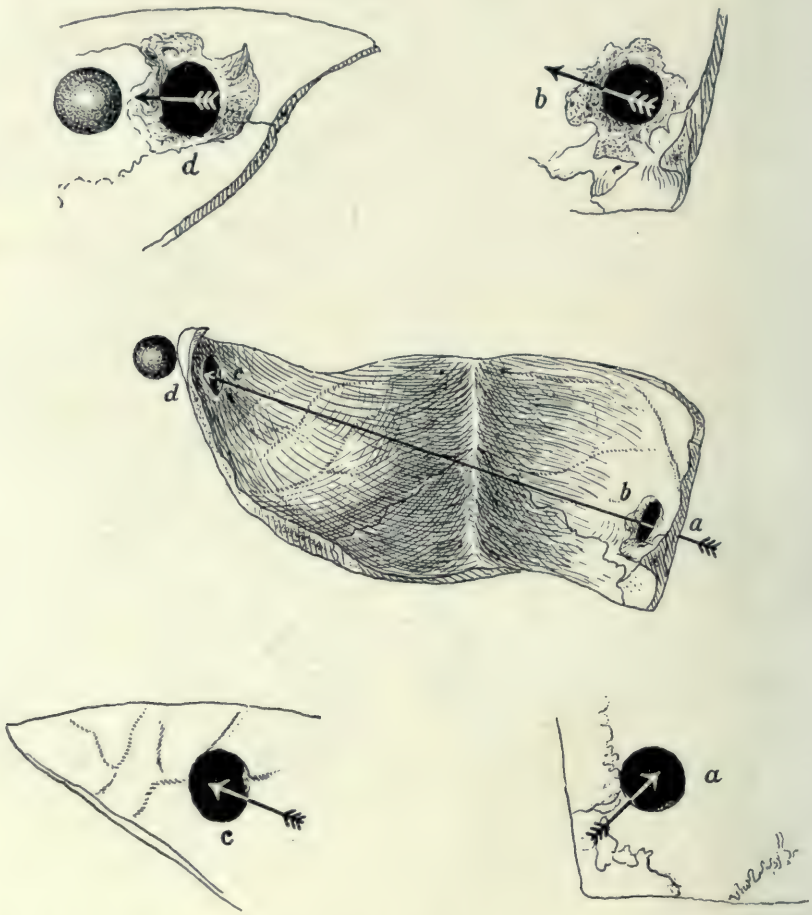


FIG. 470.—No 1.253. A series of sketches to show the entrance and exit apertures caused by a shrapnel ball which was arrested in the tissues of the scalp at the wound of exit. The central sketch shows the track of the missile in the parieto-occipital region of the skull. The adjoining sketches show the apertures of entrance and exit on both sides of the skull.

In *Figs.* 471*a*, 471*b* we represent the skull (No. 1.023) which illustrates better than any other in the Collection the disruptive or 'explosive' effects which result from missiles of high velocity fired at close range. In this case the wound was self-inflicted—a revolver of a service pattern being fired so that the bullet entered the mouth, pierced the base of the skull, and made its exit in the region of the left parietal eminence. The palate and the walls of the nasal cavity have been comminuted, but the most remarkable effects are to be seen in the region of the exit wound (*Fig.* 471*b*). The missile comminuted and carried away the bone lying in its immediate track, thus leaving a large aperture of exit. Surrounding the aperture of exit is an irregular circle of large fragments, detached and raised up by the force of the missile. From the fragmented circle surrounding the

aperture of exit there pass forwards on the left side of the skull a double series of fissures which really join the aperture of exit in the left parietal region to the entrance wound in the region of the mouth. The missile, as it were, during its passage through the head, tended to lift up or blow out the left side of the skull, because its course lay closer to the surface of that side, which was consequently the less resisting. Thus we have in this specimen simply an exaggeration of the effects seen in every through-and-through wound of the skull—a tendency for the apertures of entrance and exit to be joined by one or more fissures, and for a circular area of bone surrounding the aperture of exit to be raised up and broken into a series of fragments. It is unnecessary to add that death was instantaneous in the case just narrated.



FIG. 471*a*.—No. 1.023. Lateral aspect of skull, showing destructive (explosive) effects following a missile of high velocity fired at close range. The arrow shows the course of the missile—a revolver bullet.

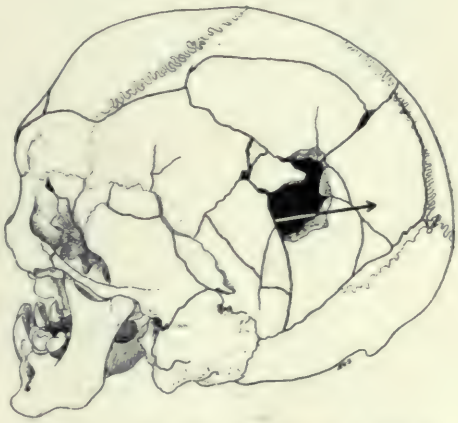


FIG. 471*b*.—No. 1.023. The aperture of exit, surrounded by a circle of large fragments of the left parietal. The course of the missile is shown in *Fig.* 471*a*.

Another specimen (No. 1.163) which illustrates the disruptive effects which attend a through-and-through wound is shown in *Fig.* 472. The missile, a fragment of shell, entered the left temporal region, severing the zygoma, and then pierced the cranial cavity behind the left angular process of the frontal, at the site of the middle meningeal vessels and third frontal convolution. Pursuing its oblique course through the frontal lobe, the missile escaped at the left frontal eminence, leaving behind it a ragged aperture of exit. The aperture has been enlarged by the removal of a loose fragment by the surgeon during an exploratory operation. The apertures of entrance and exit are joined by a fissure, while the whole region of the forehead surrounding the aperture of exit is broken by radiating and circular fissures. Beyond the immediate track of the missile, secondary effects are seen in the fracturing of the left maxilla (*Fig.* 472), and destruction of the interorbital septum and roof of the left orbit. The soldier who was the subject of this injury was admitted to hospital on Sept. 11, 1918; an exploratory operation was done the next day; and death from meningitis occurred on Sept. 16.

Extensive destructive effects may follow glancing or gutter wounds of the skull, as is shown by specimen No. 1.0221, depicted in *Fig.* 473. The soldier from whom this specimen was obtained was wounded on Dec. 5, 1917. He lay in hospital unconscious and pulseless for four days, with a horizontal lacerated wound in the left temporal region. Bone, blood, and brains were removed from the wound. Gas infection set in, and death occurred on Dec. 9. At the post-mortem examination, the left hemisphere of the brain was found diffluent and foul. No missile was found within the skull. The aperture

measures 52 × 20 mm., and is situated in the left parietal bone, just above and behind the squamous suture. Its edges are undercut except in two parts of the upper and lower

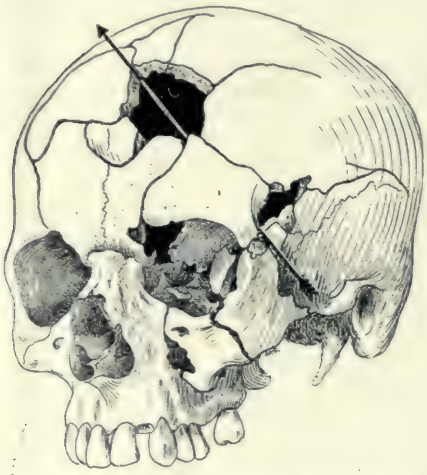


FIG. 472.—No. 1.163. A skull showing the disruptive effects of a through-and-through wound in the left frontal region. The course of the missile (a fragment of shell) is shown by the arrow.



FIG. 473.—No. 1.0221. A skull showing extensive effects from a glancing or gutter wound in the left temporal region. The inset shows a remote vertical fissure of the right maxilla.

margins (*Fig.* 473). The missile, probably a bullet, struck a glancing blow, its course being from before backwards. Two fissures descend from the lower margin of the aperture, one to the lambdoid suture and occiput, another to enter the roof of the ear and base of the skull. From the upper margin a fissure ascends to the sagittal suture, while another passes backwards from the posterior end of the aperture.

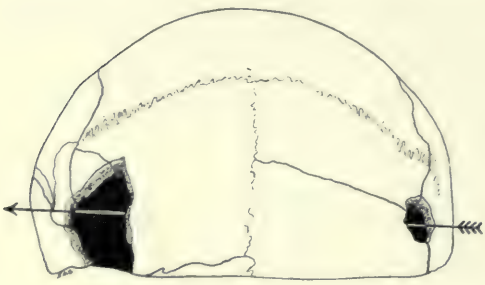


FIG. 474.—No. 1.1611. Frontal view of calvaria, showing a through-and-through wound, the missile—probably a bullet—passing in the direction of the arrow. A persistent metopic suture is shown.



FIG. 475.—No. 1.1612. Frontal view of calvaria, showing a through-and-through wound in the frontal region, the direction of the missile being indicated by an arrow. Corresponding fissures are present in both specimens depicted in *Figs.* 474 and 475.

There are also remote or indirect effects seen in the vertical fissuring of the left maxilla, the fissuring of the roofs of both orbits, of the floor of the middle fossa, and of the left temporal area of the frontal bone.

The two specimens depicted in *Figs.* 474 and 475 illustrate bifrontal perforating (through-and-through) wounds, both proving rapidly fatal. In *Fig.* 474 (No. 1.1611) the missile, probably a bullet, entered above and lateral to the left frontal eminence, and made its exit at a corresponding point in the right temple. It will be noted there is a persistent interfrontal or metopic suture, and that the fissure which one expects to join the apertures of entrance and exit is really present, but is interrupted by the metopic suture. It will also be noted that from the aperture of entrance a fissure ascends towards the vertex, while another descends towards the left temporal region. The aperture of exit has been enlarged by the removal of a loose fragment. From the aperture a fissure passes backwards along the roof of the skull. In *Fig.* 475 (No. 1.1612) a wound very similar to the last described is shown, only the bullet traversed the forehead in a contrary direction, from right to left. In this case the aperture of entrance has been enlarged by the surgeon, while from the wound of exit a loose fragment has been taken away. In this instance the missile has traversed the head nearer to the frontal poles than in the specimen illustrated in *Fig.* 474, and hence the inter-apertural fissure is better marked, being gaping, and joined by secondary fissures. From the wound of entrance two fissures pass backwards, enclosing between them a triangular or *wing-shaped* area. Two minor fissures pass backwards from the aperture of exit.

In specimen No. 1.1621, which is shown in *Fig.* 476, the effects of a through-and-through wound of a superficial nature—almost a glancing or gutter wound—are well illustrated. The missile, a bullet, entered near the middle of the forehead, and passed out on the right side of the skull in the line of the coronal suture. The projectile thus pursued an oblique course through the frontal lobe of the right hemisphere. The calvarial wall between the apertures has been lifted out and broken. The bone round the



FIG. 476.—No. 1.1621. Shattering effects of an oblique and superficial through-and-through bullet wound. The missile entered in the mid-frontal region, and escaped at the right coronal suture.

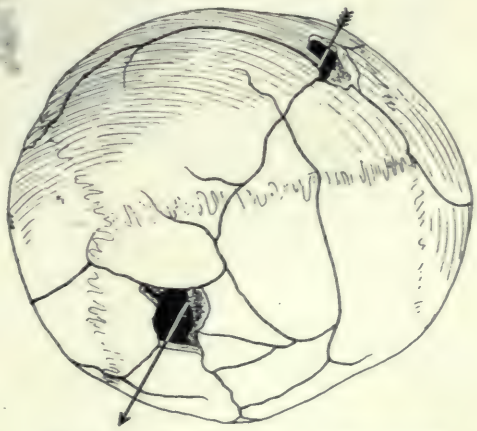


FIG. 477.—No. 1.2504. Showing the effects of a superficial oblique through-and-through wound in the vertex region of the skull. The direction of the missile is shown by an arrow from the left coronal region to above the right parietal eminence.

aperture of exit shows not only the usual radiating fissures, but also the irregular circular fissure which delimits the surrounding fragments, a form of injury already called attention to in connection with *Fig.* 471*b* and other illustrations. Although the fissures seen at the wound of entrance look, at first sight, as if they belonged to an irregular type, yet the usual arrangement is present. The two fissures which are seen to proceed from the wound of entrance towards the wound of exit, and enclose between them a triangular area, really represent the handle end of a racket-shaped fissure which usually surrounds an aperture of exit. The handle of this circular racket-shaped fissure represents the inter-apertural fissure. From the aperture of entrance two other fissures issue, and enclose

between them an area on which is situated the left frontal eminence. We see that these two fissures bounding the sides of a triangular area of bone are present at the point of impact of all missiles which impinge on the skull tangentially. In *Fig.* 477 (No. 1.2504), another superficial through-and-through wound is represented. In this case the missile has passed—as shown by an arrow—in an oblique direction across the vertex region of the calvaria, entering behind the left coronal suture, and passing out well above the right parietal eminence. There is seen the usual inter-apertural fissure, and a series of large fragments surrounding the aperture of exit which are partially delimited by a circular fissure. From the aperture of entrance pass out two fissures, in this case almost at right angles to the inter-apertural fissure, in place of being at a very obtuse angle to it. In both cases represented in *Figs.* 476 and 477 the wounds proved rapidly fatal.

In *Fig.* 470 we have represented the clean-cut perforations, with absence of fissuring, which usually attend the infliction of a through-and-through wound by a shrapnel ball. In *Fig.* 478 (No. 1.1613) is represented a somewhat similar case where a shrapnel ball entered the skull just behind the right external angular process of the frontal bone and made its exit above the left frontal eminence. The subject of this lesion was wounded at Camières, Oct. 7, 1915, and after a period of apparent recovery, died on Dec. 19, from an abscess in the right frontal lobe. The aperture of entrance shows a smooth marginal deposit of new

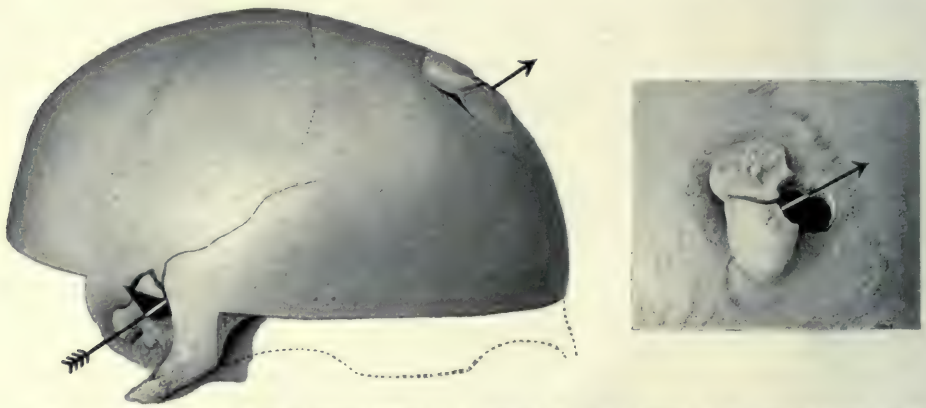


FIG. 478.—No. 1.1613. A bifrontal wound caused by a shrapnel ball which passed in the direction shown by the arrow. The inset shows the wound of exit. The soldier lived for two months after being wounded.

bone at its lower side and a fragment of detached bone at its upper side. There is an attempt at an inter-apertural fissure starting from the wound of entrance—which, by the way, shows marks of infection and suppuration. At the wound of exit there are two raised everted fragments which have become reunited to the skull at their bases by true bony union, but there has been no attempt to fill in the aperture by new bone. On the other hand, there are distinct signs of absorption in the outer table in the neighbourhood of the aperture of exit—an indication of suppuration.

In *Fig.* 479 (No. 1.022) we represent one of the most puzzling lesions to be found in the War Office Collection. The skull shown is that of a soldier admitted to No. 2 Canadian Casualty Clearing Station on March 8, 1917, with a gutter wound in the upper left parietal region of the head. The wound was excised and loose bone fragments were removed, but the patient died from acute encephalitis on March 13. From the oblong aperture in the left parietal bone a fissure passes forward to the frontal region, where it divides into two gaping branches, in the fork of which is a raised or everted triangle of bone. The appearance of this frontal fragment suggests that a missile which had entered the skull at the parietal aperture had passed forwards in the brain and struck the frontal bone, thus everting the triangular area. We presumed at one time that this had been the case, and hence we have inserted an arrow to represent the supposed direction of the missile. But a further

examination of the clinical notes, the absence of any missile from the frontal region, and the nature of the marginal bevelling shown by the parietal aperture, have convinced us that we are dealing here with a glancing or gutter wound—the missile entering at the



FIG. 479.—No. 1.022. A skull viewed on its left vertical aspect, showing an aperture caused by a glancing wound. The missile was probably a bullet which entered at the anterior and lower end and emerged at the upper and posterior end of the aperture. See text for fuller explanation.

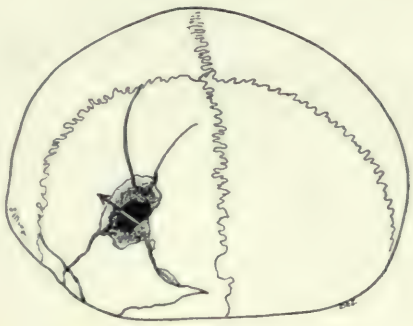


FIG. 480.—No. 1.1675. Frontal region of calvaria, showing the exit aperture of a bullet which entered the skull near the occiput and emerged at right angles to the plane of the frontal bone.

anterior end of the aperture, and emerging at its upper or posterior end. We have thus the usual V-shaped arrangement of fissures at the point of impact and point of emergence. Only in this case we are at a loss to explain the gaping Y-shaped fissure in the forehead, with the raised and everted area in the fork of the frontal fissure. We have set side-by-side with *Fig.* 479 an instance (*Fig.* 480) where a bullet has emerged from the skull, not tangentially as in *Fig.* 479, but at right angles to the cranial wall. In this specimen (No. 1.1675) the bullet entered at the occiput. The aperture of exit in the frontal bone is surrounded by radiating series of fissures. In this case death took place soon after the soldier was admitted to hospital.

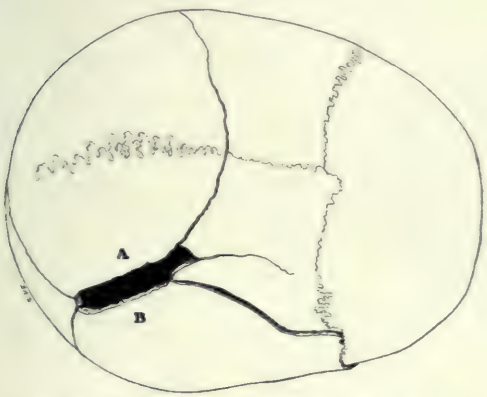


FIG. 481.—No. 1.2514. An oblong aperture in the right parietal bone caused by the graze of a bullet which entered at the lower and hinder end and emerged at the upper and anterior end. The specimen shows the typical arrangement of fissures which accompany such injuries.

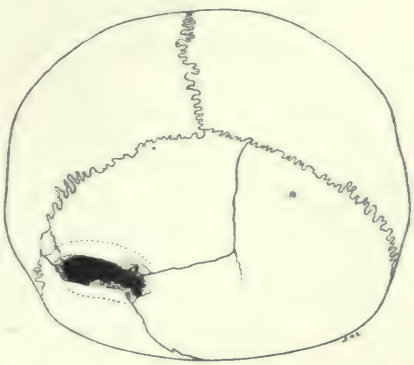


FIG. 482.—No. 1.1431. A tangential wound in the right frontal region. The stippled line indicates the area of undercutting.

In specimen No. 1.2514 we have a typical representation of the bony fissuring which follows a glancing impact of a bullet, but it was some time before we recognized the true nature of the type of injury represented by this specimen. In the absence of full clinical

details, we at first supposed that such an oblong aperture as is shown in the right parietal bone (*Fig.* 481) was caused by the penetration of a fragment of shell, and that the fissures which pass into the vertex, one from each angle of the aperture, were produced by the sharp corners of the penetrating missile. The true explanation of such a lesion as is shown in the figure is now beyond doubt, and is due to the glancing impact of a bullet, which in the present case has entered at the hinder and lower end of the aperture, and emerged at its upper, anterior, and more fragmented end. At the point of impact and entrance two fissures spread backwards, bounding a posterior triangular area ; while at the point of emergence two fissures, more extensive and more open, spread forwards. We do not offer here a physical explanation of this arrangement of fissuring ; we simply note that, in all tangential wounds of the skull, such a series of fissures as is shown in *Fig.* 481 can be identified. The missile tends to raise the bone on each side of its track as flaps or lids (*Fig.* 481 A, B).



FIG. 483.—No. 1.291. A gutter wound in the left lambdoid region. The missile passed from the upper towards the lower end of the aperture.

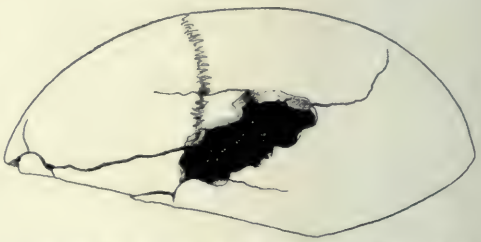


FIG. 484.—No. 1.254. A large and irregular aperture in the anterior and lower part of the left parietal bone—the result of a gutter fracture.

In *Fig.* 482 (No. 1.1431) a more limited aperture of the same nature as in *Fig.* 481, but in the right frontal region, is to be recognized. In this case the bullet came from the right and from behind, and glanced across the right frontal eminence. The stippled line round the aperture indicates the area from which the inner table has been detached —there being in this case much undercutting.

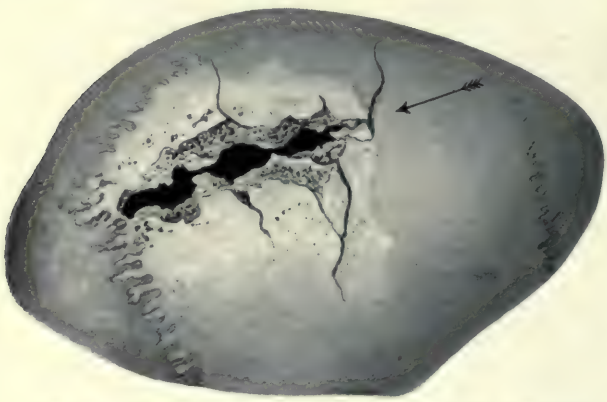


FIG. 485.—No. 1.285. A gutter wound of anomalous type in the upper and posterior part of the right parietal bone. The bone bounding the aperture is undergoing the changes which result from infection.

In *Fig.* 483 (No. 1.291) there is represented a gutter wound crossing the left lambdoidal suture obliquely from above downwards. The subject from whom this specimen was obtained was wounded by a fragment of high explosive on May 7, 1915, and died on June 11 of the same year. Brain matter extruded from the wound ; this was removed, and the wound enlarged in a downward direction. We have here the usual double-winged type of cranial gutter wound. From the upper end of the aperture—which we upposed to be the point of impact—two fissures spread out, one following the lambdoid suture, which in this case was still open, for the soldier was only 19 years of age. From this lower end of the original aperture two other fissures diverge, one following the lambdoid suture, the other passing down the occipital bone to reach the foramen magnum. In

this specimen we see the tendency of fissures to follow the line of unclosed sutures, and of the bone at each side of the aperture to be raised up as flaps or wings (*Fig.* 483 A, B).

In *Fig.* 484 (No. 1.254) an aperture is shown in the anterior inferior angle of the left parietal bone, measuring 50 × 20 mm. The soldier, a Newfoundlander, was struck on the left side of the head by a fragment of shell, April 25, 1917. Brain matter escaped: there was paralysis of the right limbs. Meningitis set in, and death followed on April 29 The arrangement of fissures is anomalous, particularly the gaping crack which runs downwards and forwards to the frontal region.

It is a misfortune that some of the more interesting specimens in the War Office Collection were obtained during the earlier phases of the War when full clinical notes could not be secured. One of these is shown in *Fig.* 485 (No. 1.285), the calvaria of a soldier who died from an abscess of the brain some weeks after being wounded. There is a gutter-like opening above the eminence of the right parietal bone. It is difficult to determine whether the missile passed along the gutter from before backwards, as is shown by the arrow, or in the reverse direction. There are no fissures connected with the posterior end of the aperture, nor is the lambdoid suture, which crosses it, at all opened. From the other end fissures proceed at right angles, and there is also a pair of fissures opposite the middle of the aperture. The bone in the neighbourhood of the aperture shows all the signs of infection. There is no attempt at the deposition of new bone; the bone seems to have necrosed for some distance beyond the roughened and porous margins of the wound. One notes that all the vascular foramina in the outer bony table near the wound have become enlarged.



FIG. 486.—No. 1.142. Gutter wound in the left frontal region, with fragments driven inwards, causing laceration of the frontal lobe.

In *Fig.* 486 (No. 1.142) a glancing or tangential fracture of the frontal bone is depicted. The opening is 20 × 15 mm., showing within its floor the fragments of bone which were driven inwards by the missile. In this case a fragment of shell simply grazed the forehead. When one looks along the contour of the frontal bone, and notes the margins of the gutter, it is plain that the missile did not plough into the bone to a greater depth than perhaps one millimetre, and yet the impact has been sufficient to drive the fragments inwards. Whether the dura mater was ruptured or not there is no clear record, but a note has been made at the post-mortem examination that the frontal lobe was lacerated. The soldier was wounded by fragments of high explosive on June 7, 1917, and died on June 10. It will be noted that while two fissures diverge from the upper end of the frontal aperture, as is usual in glancing wounds of the cranium, at the lower end one of the fissures is indicated by a mere vestige.

Figs. 487*a*, 487*b* are drawn from specimen No. 1.2011, where death resulted from the detachment of an area of the inner table which was situated over terminal branches of the middle meningeal vessels. It will be seen that a small fragment of high explosive has struck the outer table of the left parietal bone near its anterior superior angle, a minute part of the missile becoming embedded at the point of impact. The inner table has been detached from an area twice as large as the contused area of the outer table.

In specimen No. 1.207 (*Figs.* 488*a*, 488*b*) there is represented a kind of wound very similar to the one just described, but showing injuries of a less degree. A fragment of high explosive—the soldier was struck in many other parts besides the head—has been embedded in the outer table of the right parietal bone just above the parietal eminence. The inner table is slightly depressed and fissured, but not detached as is the case in

Fig. 487*b*. The soldier was wounded on May 3, 1917, and died on May 16. There was an extradural hæmorrhage at the site of fracture, with œdema of the meninges.

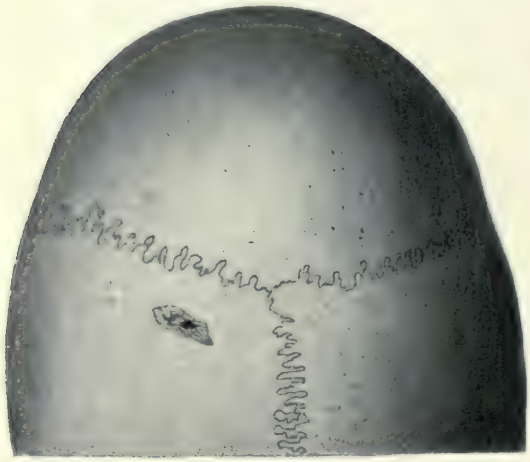


FIG. 487*a*.—No. 1.2011. Outer aspect of calvaria, showing a fragment of high explosive embedded in the outer table near the anterior superior angle of the left parietal bone.

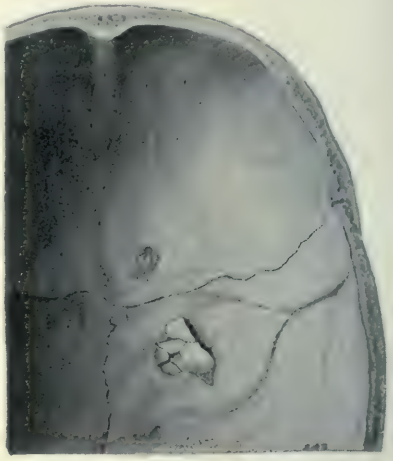


FIG. 487*b*.—No. 1.2011. The detachment of the inner table opposite the contused area shown in *Fig.* 487*a*, with rupture of meningeal vessels.

Specimen No. 1.2022 (*Figs.* 489*a*, 4 9*b*) is an example of detachment of the inner table, while the corresponding outer table has retained its normal level and contour. We

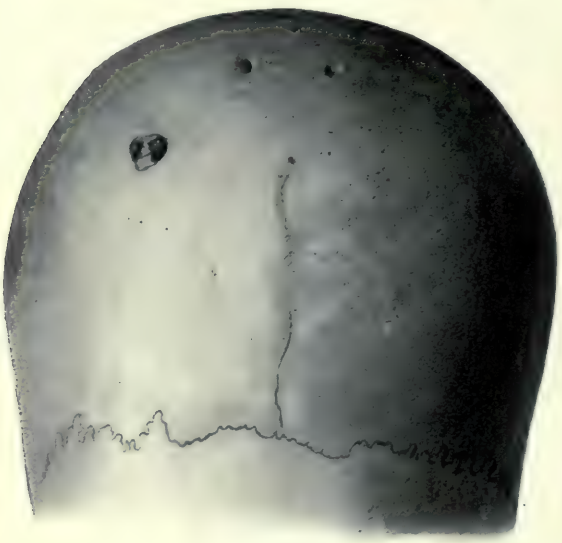


FIG. 488*a*.—No. 1.2071. Vertex aspect of cranium, showing a fragment of high explosive embedded in the outer table of the right parietal bone.

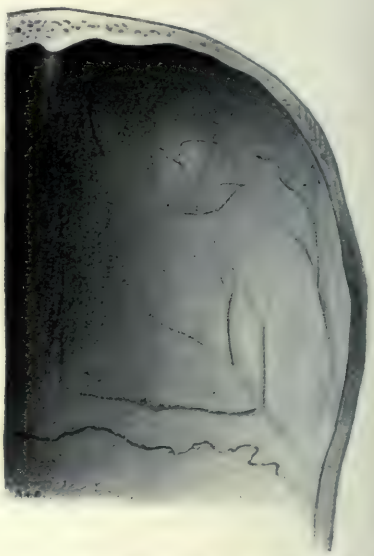


FIG. 488*b*.—No. 1.2071. Showing the inner table depressed and fissured opposite the area of impact shown in *Fig.* 488*a*.

were at first inclined to regard the injury shown in these figures as the result of a direct blow by a blunt missile ; but further experience has led us to suspect that we are

here dealing with a fracture caused by a missile moving tangentially to the contour of the parietal bone, and involving only the scalp and soft parts which cover the bone. On the outer surface of the skull, which is only 3 to 4 mm. in thickness, a fissure is seen to pass from the upper to the lower border of the right parietal bone (*Fig.* 489*a*), almost overlying the Rolandic fissure of the brain. Near the middle of this fissure there is a complex of minor fissures, which we regard as the area impacted by the missile in its tangential flight through the scalp. On looking at the interior of the parietal bone (*Fig.* 489*b*), we see that, opposite the complexity of fissures just mentioned, the inner table is extensively detached, the fragments being driven into the brain. An examination of the interior

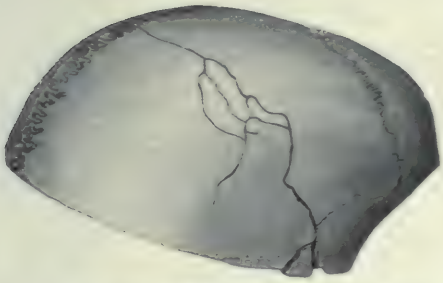


FIG. 489*a*.—No. 1.2022. Outer aspect of skull, showing a fissure descending from the upper to the lower border of the right parietal bone, the result of a glancing wound.

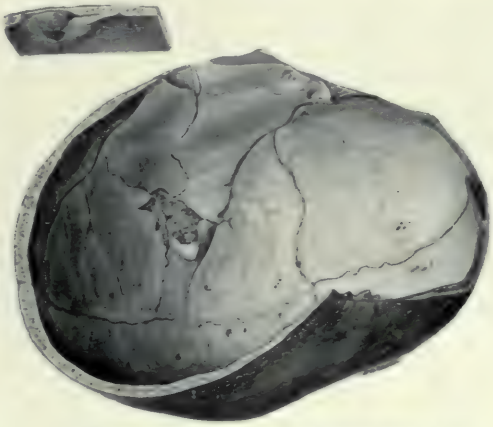


FIG. 489*b*.—No. 1.2022. The inner aspect of the specimen shown in *Fig.* 489*a*. An area of the inner table has been detached and driven into the brain.

reveals at the point of impact the arrangement of fissures characteristic of tangential or glancing blows. The usual four fissures are seen to radiate outwards, two diverging upwards and two downwards. The soldier was wounded on Aug. 15, 1917; he afterwards became unconscious, and died Aug. 25. At the post-mortem examination, the brain was septic, necrotic at the site of injury, and the meninges were inflamed.

(*To be continued.*)

A NEW METHOD OF TREATMENT FOR SUPPURATIVE ARTHRITIS OF THE KNEE-JOINT.

By Major J. EVERIDGE, R.A.M.C. T.

Current Methods of Treatment.—In spite of the dramatic progress in the surgical treatment of penetrating gunshot wounds of the knee, suppurative arthritis of this joint, when it occurs, has remained a condition often defeating our most painstaking endeavours.

Its treatment has been attempted by both surgical and chemical methods, the former having for their object joint drainage, the latter aiming at the destruction of bacteria by the application of one or another antiseptic. That joint drainage by purely operative measures is unsatisfactory is manifest from the multiplicity of methods which have been described from time to time. Anterior and posterior incisions, the turning up or turning down of a patellar flap, joint resection—all have had their adherents. The drainage tube inserted in the interior of the joint has long since been discarded. Similarly, the diversity of the antiseptics that have been used indicates the uncertainty of the action of each one of them. Either it is too irritating and still further lowers the vitality of the articular components already almost overcome by the septic processes, or, if it is non-irritating, its germicidal effect is so weak as to make its use of doubtful value. Further, to diffuse the antiseptic to all the numerous articular recesses where the germs lie hid is, in practice, impossible. The ideal antiseptic, in fact, has not yet been discovered.

After operating upon penetrating knee-joints, it has been almost the universal practice among British surgeons working in the war areas to adopt strict immobilization in the Thomas splint for at least ten days, and often much longer, after the temperature has settled.* Should suppuration occur, complete immobilization has been, more than ever, the unchallenged principle in treatment.

Disadvantages of Prolonged Immobilization.—I wish to draw particular attention to the fact that a limb long maintained at rest not only suffers muscular atrophy, but, worse, is also largely deprived of its blood-supply. The contracted state of the large arteries of the leg to be noticed when amputating a limb long immobilized is evidence of this. Further, elementary physiology teaches us that muscular action promotes the flow of blood in the veins. Finally, those experienced in war surgery are familiar with the frequency of tracking sepsis in legs where, for some reason or another, the main artery has required ligature. To illustrate this, I quote a series of 23 suppurating cases treated by me in 1917–18 by most careful immobilization with extension in suspended Thomas knee-splints; tracking took place in 17. In some, the pus tracked almost to the extremities of the limb. Four of these cases subsequently came to amputation (one in France and three in England). These facts make it appear reasonable to reconsider the advisability of complete rest in the management of such cases.

A Physiological Method of Treatment.—Realizing how great are the natural powers of resisting infection possessed by the joint, I have endeavoured to evolve a method of treatment wherein they are utilized to the utmost. I have ventured to call this system

* An article[1] I published in the *British Medical Journal*, August 24, 1918, calls attention to the tendency to employ splints for unnecessarily long periods of time. It suggests a method where, by carrying out passive mobilization at first, a wide range of movement may be established with the least risk of 'stirring up' sepsis and breaking down healing tissues in and round the joint, while at the same time the formation of anchoring adhesions is prevented.

of dealing with an infected joint the 'physiological method,' for the natural processes of repair enter largely into its rationale.

This *alternative treatment* which I am recommending is consistent with physiological and pathological axioms, though in disagreement with the well-known doctrines of Hilton. It relies for its curative effect on active movements of the joints of the lower extremity, including the knee. It must be emphasized, however, that adequate openings into the infected joint must first have been established to allow the free escape of synovia and pus; otherwise, movement will result in the dissemination of sepsis into culs-de-sac of the joint and extra-articular muscle planes.

Active movement of the joint will be begun soon after it has been operated upon, and is regulated under the supervision of the surgeon in charge or his assistant. The rationale of the procedure may advisedly be explained to the patient, who, realizing what is required, will usually lend his full co-operation. Still more will he do this when experience shows him that movements actually alleviate pain, coincident with the visible escape of pus from the joint. Active movements of not only the knee-joint but also the ankle are advisable, for the resulting contractions of the leg muscles will hasten the venous flow, thus diminishing capillary stasis, as evidenced by the absence of œdema of the foot.

To sum up, the advantages to be derived from treatment by early active mobilization appear to be five, its effects being :—

1. To hasten repair by the preservation of a good blood-supply to the tissues of the affected joint.
2. To aid drainage, as Willems[2] has emphasized.
3. To prevent extreme atrophy of the muscles, so that these will be better able to resume function when the articular inflammation is at an end.
4. To establish a process of auto-vaccination.
5. To realize the possibility of a subsequently mobile joint.

On the other hand, experience has shown that the treatment is not advisable in cases with gross injury to the articular bone or essential tendons or ligaments; or where suppuration in the joint has gone on for sixteen days or more.

THE SYNOVIAL FLUID.

The synovial fluid in the knee-joint is of such importance in the method of treatment I am advocating, that it is worth while to discuss its nature and modes of reaction to infection in detail.

Bacterial Invasion.

1. In 70 to 80 per cent of the cases of penetrating wounds of the knee-joint, this fluid at the original operation shows that 'soiling' has occurred. In most it is not possible to see and recognize organisms in it; only on cultural examination can their presence be determined.
2. Where the 'toilet operation' has been successful, these organisms disappear. Subsequent effusion, should it occur, is found to be sterile.
3. Where the 'toilet operation' has failed, as rendered apparent by the persistence or recurrence of the clinical signs of inflammation more than four days after operation, bacteriological examination reveals organisms in profusion by both direct and cultural methods.

According to Sacquépée (quoted by Gosset[3]), in the first few days after joint penetration the number of visible germs in the articular effusion is appreciably less than in wounds of bone or muscle It is even the rule that in the first twenty-four hours direct examination reveals no organisms. Cultures, however, demonstrate their presence even when the examination is practised very soon after the wound. Where circumstances permit of further examinations, it is almost always found that there is a multiplication in germs up to about the sixth day, when symptoms of *infection* begin to arise.

The Cellular Elements.

1. At the original operation the identification of cells typical of inflammation

is generally prevented by the presence of red and white blood-cells resulting from a hæmorrhage into the joint.

2. In the absence of such a hæmorrhage, a preponderance of leucocytes is not pathognomonic of severe septic infection of the joint.

3. A differential leucocyte count affords evidence in determination of infection. An 80 per cent polynuclear count marks roughly the dividing line between good and bad prognosis (Lazarus Barlow[4]).

4. The presence of extracellular organisms and the absence of phagocytosis, when suppuration has lasted for ten days, point to a severe infection and limitation of powers of resistance. Too much reliance, however, should not be put upon this observation.

The following changes in the nature of the fluid escaping from a joint, during the progress of suppurative arthritis, to a certain extent reflect the clinical evolution of the intra-articular inflammation. Three stages may be recognized :—

A. Developing.

1. (*a*) Synovial fluid discoloured by altered blood ; (*b*) Albuminous fluid like coagulating white of egg.
2. Sero-purulent fluid.

B. Established Suppuration.

3. Pus. (*a*) Thick and creamy in staphylococcal infection ; (*b*) Thinner and less viscid in streptococcal infection.

C. Subsidence.

4. Pus with semi-solid curds.
5. Curds floating in a clearer fluid.
6. Synovia, clear and limpid.

The appearance of the last two types of escaping fluid is valuable as evidence of resolution of intra-articular inflammation. Histologically, the last reveals few polymorphonuclear cells and, as a rule, no extracellular organisms, the few bacteria present being intracellular.

(At this stage, should large open wounds be present with healthy vascular granulations, and if no pus is apparent, either as a secretion of the granulating surface or escaping from a sinus leading to necrosed bone, it is safe to carry out partial or complete secondary suture. This step is advisable, for dense cicatrices, which are subsequently of considerable inconvenience, may best be avoided by early suture.)

Synovial Fluid as a Natural Germicide.—A joint subjected to an irritant, whether mechanical, chemical, or bacterial, reacts by an inflammation of the synovial membrane and the outpouring of an excess of synovial fluid into the articular cavity. In which articular components do the germicidal properties chiefly reside ? The only three tissues which can supply this protection are :

(1) The synovial membrane ; (2) The synovial fluid ; (3) The cartilage (either the menisci or that clothing the bone).

On account of the avascularity of the third, only limited powers of resistance can be ascribed to this structure. The synovial membrane, on account of its good blood-supply, should be competent to protect itself.

The most valuable germicidal agent of the joint must be the synovial fluid. This, after all, is but slightly altered from blood plasma, and no doubt is endowed with all the protective qualities which the blood itself possesses. We should expect to find that the protective value of it would vary directly as the supply of freshly oxygenated blood. The supply is largely governed by muscular action, involved in active movements. A flushing of the interior of the joint with fresh synovia, especially the more vulnerable components, such as the cartilages, I believe to be a factor of importance in the natural recovery from joint infection.

Sacquépée's observations, mentioned already, coincide with the opinion held by Veillon,[5] who regards synovia as being powerfully germicidal provided that it is freshly secreted ; if allowed to stagnate, it loses this property, and becomes instead a good culture-medium for bacteria.

It appears probable that the operation of paracentesis followed by the injection of an antiseptic fluid, referred to by Lockwood[6] and others, owes its success in arresting sepsis in certain early cases of suppurating knee-joints to the withdrawal of synovial fluid rather than to the antiseptic instilled. It is not easy to see how a solution such as 2 per cent formalin-glycerin could kill all the germs in an infected joint ; many of these lie concealed in synovial recesses and in blood-clot far beyond the reach of any antiseptic injection.

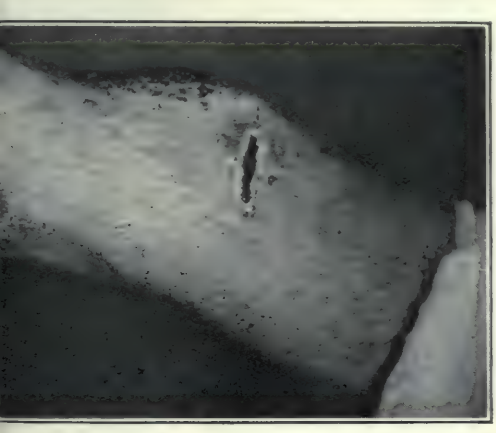
Describing penetrating gunshot wounds of the knee-joint, various observers give the percentage of instances in which 'soiling' of the synovial fluid with organisms has occurred as between 70 and 80. Where a fragment of high-explosive shell is lodged in the joint, the introduction of germs is bound to have occurred : yet the vast majority of such cases run an aseptic course after the removal of the foreign body and the performance of a 'joint toilet' on the lines so ably laid down by Colonel Gray.[7] The operation no doubt removes a considerable number of the organisms and infected material ; a large residue, however, must remain, and is dealt with efficiently by the synovial fluid.

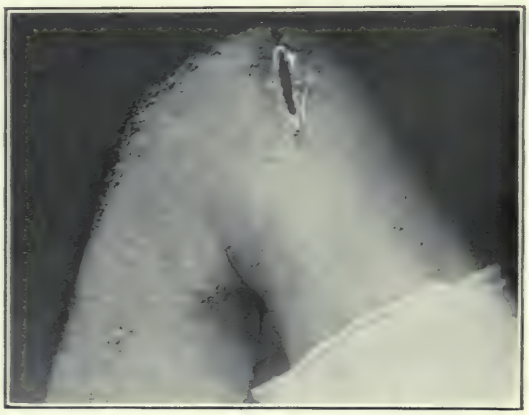
In the 20 to 30 per cent of failures, where the mass-action of infection has been too great, and clinical 'sepsis' as distinguished from 'soiling' has occurred, the aim of subsequent treatment will be : (1) To ensure a free outlet for synovia ; (2) To preserve the best possible blood-supply to the joint structures ; and, as a corollary, (3) Thereby to provide a supply of the healthiest synovial fluid, that is, synovia best equipped with vigorous phagocytes and antibodies.

PRACTICAL DETAILS OF THE PHYSIOLOGICAL METHOD.

The Formation of Adequate Joint Stomata by Operation.—The stereotyped vertical parapatellar incisions commonly used for drainage of the knee-joint have the following drawbacks :—

1. Wide gaping of the skin owing to the run of the natural lines of cleavage in this situation. The result is wounds taking long to heal, and ultimately leaving troublesome cicatrices.





FIGS. 490, 491.—The condition of the transverse arthrotomy incisions, with skin-synovial suture, one month after receipt of the wound, which produced a staphylococcal arthritis.

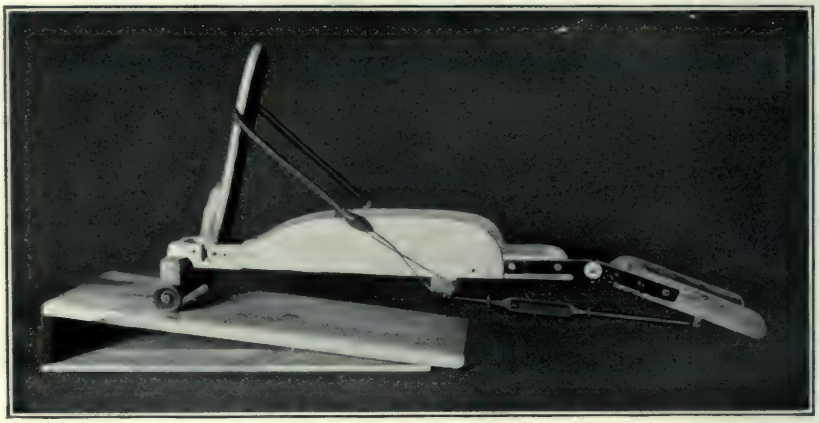
2. Joint openings which tend to close early, since the split muscle and tendinous fibres forming the capsule fall together spontaneously.

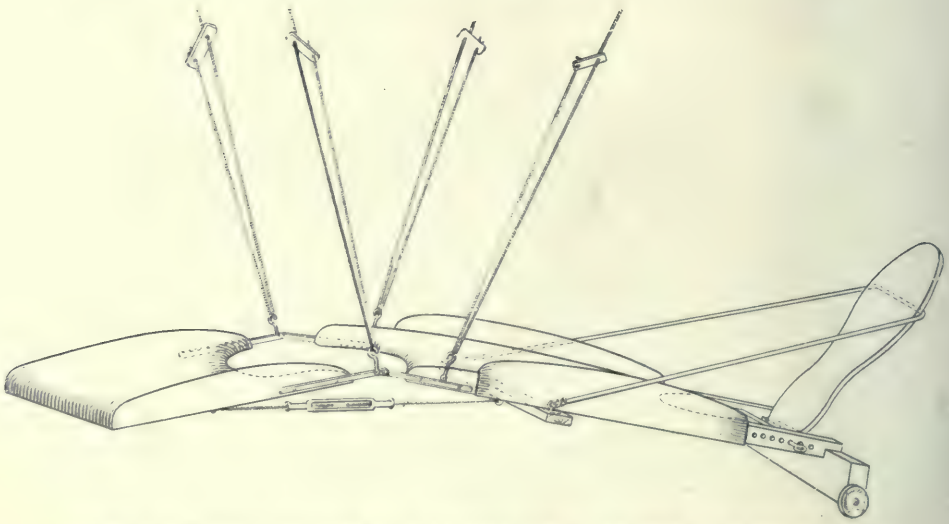
3. Interference with the blood-supply of the patella, since the main vessels, which pass transversely inwards, are divided by these incisions.

4. Troublesome hæmorrhage either at the time of the operation or some hours later. The bleeding vessels shrink away into fibrous tissue when cut, and are difficult to secure.

5. Should amputation subsequently become necessary, the anterior flap is interfered with.

Owing to these drawbacks, I have for some time past been in the habit of using transverse incisions (*Figs.* 490, 491). These remain open satisfactorily and, where active mobilization is employed, appear to drain the joint just as efficiently as the vertical incisions. They are made from the outer and inner borders of the patella, commencing at





FIGS. 492, 493.—'Active movement' splint. It can be made rigid by fixation of the adjuster below the knee. Note the adjustable foot-piece, supported by elastic slings.

the junction of the upper and middle thirds of the bone, and continuing for a distance backwards of about an inch and a half. These incisions are far removed from the lateral ligaments, which lie below and behind them. The outer incision partially divides the iliotibial band.

All structures down to and including the synovial membrane are divided in the line of the skin incisions. As a final step, the cut edges of the synovial membrane are stitched to the cut edges of the skin by a series of suspension sutures. A single layer of rubber tissue is inserted between the lips, and left *in situ* for twenty-four hours, to prevent the closure of these openings by adhering blood-clot.

If the muscles of the thigh are unusually well-developed and do not retract sufficiently to leave adequate joint openings, an elliptical segment is excised on either side.

Active Mobilization.—To persuade a patient suffering from an early suppurative arthritis of the knee to carry out active movement is, in practice, by no means easy. He is ill, weak from fever and possibly from loss of blood; and, moreover, his joint is excessively painful. Without some help he will be able to do little or nothing. He cannot raise his leg off the bed, far less bend and straighten the knee. For these reasons I have constructed an apparatus, the description of which follows, by means of which gravity is practically eliminated.

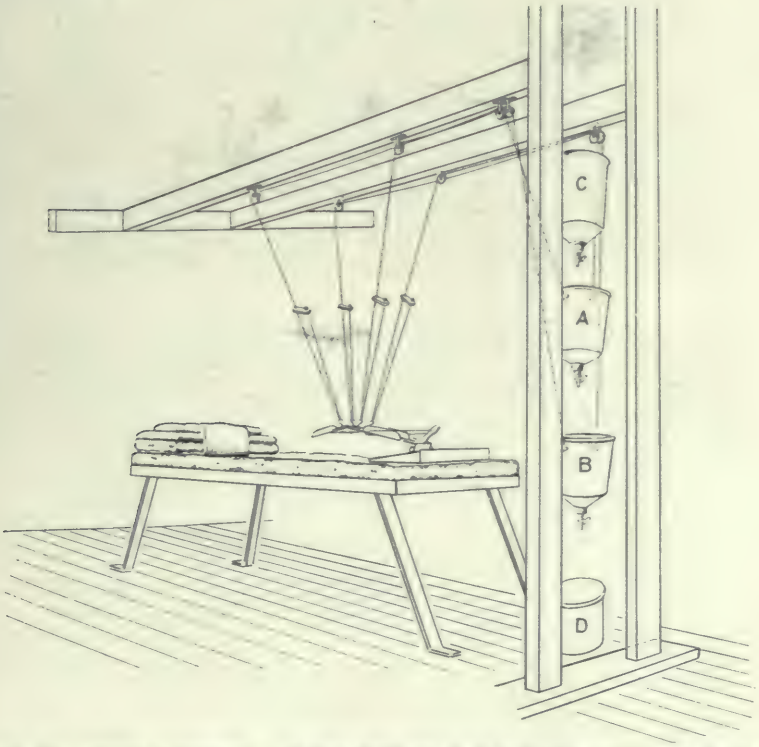
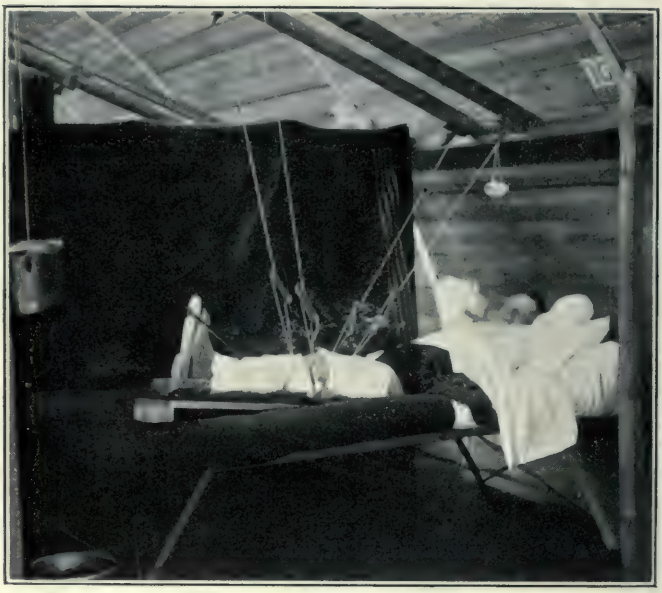


FIG. 494.—Diagram of apparatus. The splint supporting the leg is partially counterpoised by the conical sand reservoirs A and B. The shape of the reservoirs enables an easy adjustment of the weight of sand, for, by means of a tube of outlet controlled by a tap in each, sand can be allowed to flow from one to the other. C is not a counterweight; it is a fixture, and acts as a cistern for the supply of any additional sand necessary to A, or through A to B. D is for waste sand (excess from B).

APPARATUS.—This comprises: (1) A suitable splint; (2) An overhead counterpoise system.

1. *The Splint* (*Figs.* 492, 493).—This is an elaborated back splint with foot-piece, and possesses the following features:—(*a*) It is guttered to fit the shape of the leg. (*b*) It is interrupted, where it lies behind the knee, to give access for inspection and dressings. (*c*) The metal bars bridging the interval are jointed. (*d*) An adjuster is fitted like that supplied with the standard McIntyre splint. This is made easily

detachable; when removed, there is freedom for knee movements. (*e*) A footpiece is supplied, adjustable in position according to the length of the leg. It is pivoted on





FIGS. 495, 496.—Demonstrating the apparatus in use.

the adjusting pin, and held up by two elastic slings. Thus the foot is maintained in dorsiflexion when at rest. (*f*) Running wheels are attached below the foot end of

the splint. These prevent friction, and allow a free excursion up and down a platform on which the splint rests.

2. *The Counterpoise System* (*Figs.* 494, 495, 496).—That shown in the accompanying figures may appear somewhat complicated. It is the standard pattern I have established in France for the treatment of suppurative arthritis and other conditions of the knee-joint. It has many practical advantages, but an enumeration of these would somewhat complicate the present consideration.

All that is really essential is four pulleys attached somehow above the leg. These transmit four cords, two of which are attached just above, and two just below, the hinges of the splint. At their other ends are fixed counterweights (sandbags, etc.). These are not quite heavy enough to suspend the leg in the air. They merely serve to overcome most of the force of gravity. With this arrangement the patient's limited energy may be economically spent on movements at the knee, and not wasted on the purposeless act of lifting the leg from the bed.

Active movements are at first carried out under the observation of the surgeon or his trained assistants. The splint is fixed by re-applying the screw adjuster at all times when jars, twists, or strains might occur, such as during sleep, nursing procedures, etc. Experience shows that normal movements of flexion and extension are singularly painless provided there is a free outlet for fluid from the joint, preventing any rise in intra-articular tension.

Patients soon become interested in the routine, and enjoy considerable relief of pain when the daily movements are carried out. In fact, they often ask that the splint may be released, in order to ease their discomfort by movement. Emphasis is again laid on the importance of movements of the foot. Active contractions of the muscles of the leg stimulate the flow of blood and prevent the occurrence of œdema from venous stasis. Possibly, also, contractions of the gastrocnemii help to massage up pus from the posterior compartments of the knee-joint.

The physiological method, in order to be of service, must be instituted *early*. It is useless to commence it when all the joint structures are becoming disintegrated by septic processes, and especially when the cartilages are becoming eroded.

For this reason I believe it unwise to resort to the operation of arthrotomy, lavage, and closure, where signs of sepsis occur as late as a week after the date of the original wound or primary operation. It is wiser to avoid the waste of time incurred by this operation, which, more often than not, fails to arrest sepsis at so late a stage. Each day's delay renders the mobilization method less likely to succeed, and lessens the chance of obtaining a movable joint at the finish.

PARTICULARS OF CASES.

To illustrate the type of case which lends itself to this method of treatment, the following may be quoted as good examples : —

Case 14.—L.-Cpl. T. Received a shell wound of right thigh and knee, Oct. 15, 1918. At the casualty clearing station a piece of high-explosive shell was removed from the extensor muscles just above the outer angle of the patella. The wound was excised and sutured ; the knee-joint at this operation did not appear to be involved. The patient was admitted under my care on Oct. 17. On Oct. 21 the knee was painful and slightly swollen, the temperature 100°. On paracentesis the following day, turbid coagulating fluid was withdrawn from the joint. Histologically examined, this was seen to be rich in pus cells and staphylococci. In consequence, the wound was reopened, internal transverse arthrotomy (by the method described above) was done, and the joint washed out with saline. Immediate active mobilization was instituted. Movements were good from the first, and the temperature and pulse settled in the course of a few days. On Nov. 4 active flexion could be carried out through a range of 100°, and by this time the fluid escaping from the joint had become clear and limpid, resembling typical normal synovia. Two days later fluid had ceased to escape. By Nov. 18 the wounds were healing well, there was full range of active movement, and the patient was getting up and able to walk a few steps. On Nov. 20 he was sent to England, with the right knee-joint normal to all outward appearances,

except for incompletely healed wounds. The accompanying photographs (*Figs.* 497, 498) show the range of movement thirty days after the receipt of the original injury. Two and a half months from the date of injury, the report from England stated that the wounds were healed, there was full range of movement, no swelling of the joint, and the patient could walk two miles.



FIG. 497.—*Case* 11, one month after shell wound of the knee which produced a septic arthritis.



FIG. 498. The same case, showing that at this time a complete range of movement was possible.

Case 17.—Gnr. D. Received a shell wound of right knee on Oct. 23, 1918. The fragment of shell was removed the following day at a casualty clearing station ; the joint was washed out with Dakin's fluid and closed. The patient was admitted under my care on Oct. 25, when the whole joint was very much swollen, the skin was œdematous, and there was great tension on the lower stitches of a long antero-internal arthrotomy wound. Some of the stitches were immediately removed. The next day paracentesis was done, and suppurating blood clot removed from the joint. On examination, this fluid contained pus cells, *B. Welchii*, and staphylococci in profusion. Accordingly the same day an external transverse arthrotomy with skin-synovial suture was done. At the same time the lower part of the original wound, where it lay over the joint, was opened.

and the skin stitched to the synovial membrane. The joint was washed out with saline, and, of course, left open. In the course of eleven days the temperature had settled and active movement through 82° was easy. By Nov. 21 there was full range of active movement, and the wounds were granulating well, fluid having ceased to escape from them. On Nov. 25 the patient was getting up and could bear weight on the limb. (See *Figs.* 499—502). By Dec. 15 he was able to walk long distances without a stick, and there was hardly any perceptible lameness.

In the more virulent types of inflammation, and especially when it is associated with gross bone injury, movements towards the end of the third week may become restricted and painful. If this is not due to a collection of pus in the popliteal space, it is regarded as coinciding with erosion of the articular cartilages, and is the signal for the application of a rigid Thomas splint with extension, hope of a mobile knee being no longer entertained.



FIG. 499.—*Case* 17, five weeks after removal of missile which produced a suppurative arthritis (staphylococcus and *B. Welchii*). The lower part of the original operation wound was converted into a joint stoma.

Such an occurrence is not to be regarded as complete failure, for experience shows that the measures adopted early have served the following purposes: (1) Prevention of tracking; (2) Hastening of resolution of the septic processes within the joint by stimulation of the synovial circulation; (3) Limitation of the intensity of the inflammation and of toxic absorption.

Not the least striking feature when this treatment is carried out is the satisfactory general condition these patients preserve. Their appetites remain good; they sleep well; take interest in their surroundings; and, in fact, present an entirely different picture from that which we were accustomed to see when treatment by immobilization was carried out.



FIG. 500.—The same case, showing range of movement.

Though the tendency to track is overcome, a localized abscess frequently occurs in the popliteal space.* It is not quite clear whether this comes about by an extension through the back of the joint by way of the bursæ, or by a track superficial to the condyles. These abscesses occurred in 10 out of 23 cases treated by the physiological method.

* The occurrence of pain, swelling, and œdema in the popliteal space is an indication for an immediate exploratory incision.

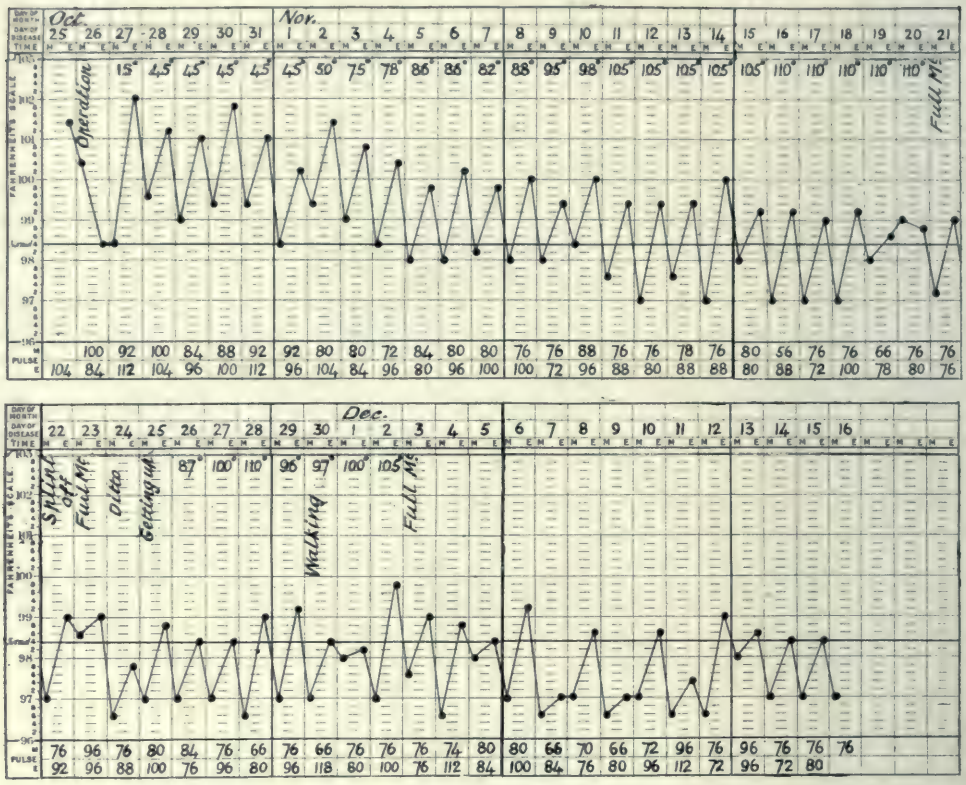


FIG. 501.—Temperature chart of *Case* 17. The increment in range of active movement is indicated by the number stated in degrees. Note the steady pulse-rate and gradual subsidence of temperature.



FIG. 502.—Skiagram of *Case* 17 at the sixth week. To demonstrate that absorptive changes in the bone are very limited, extending only a short distance into the depth of the cancellous tissue. There is no subperiosteal deposit of new bone.

That a joint treated by the physiological method may sterilize itself is evident from the following case :—

Case 8.—Bdr. M. Developed a streptococcal arthritis after a shell wound, which caused a very septic compound fracture of the fibula, and injury to the popliteal artery necessitating its ligature in addition to the joint lesion.

The joint was treated by the physiological method. On the twenty-ninth day it became necessary to amputate, owing to extensive suppuration in the lower part of the leg, the consequence of ligature of its main artery. Examination of the amputated limb showed that the interior of the knee-joint was in a satisfactory state. There was no pus, merely a little clear fluid, upon which the pathological report was as follows : in 50 fields there were 114 polymorphs, 34 lymphocytes, and 4 cocci.

Such a degree of recovery in a very acute streptococcal joint after twenty-eight days' treatment offers convincing proof of its efficacy. The joint fluid, in fact, revealed a condition of cleanliness which almost conformed to Carrel's standard of 'clinical sterility.'[8]

The *Table* on p. 578 shows that about 50 per cent obtained a mobile knee. There were no deaths in the series, and the one amputation (*Case* 8) was necessary on account of intractable suppuration in the leg resultant upon ligature of the popliteal artery ; the knee-joint, subsequent examination showed, had settled down completely. In each of these cases the knee-joint was definitely infected and in one of the various stages of suppuration ; not one was merely a 'soiled' joint. It will be observed that in no instance where movements were commenced after the seventh day did a mobile joint result. Mobilization, however, in these cases undoubtedly served a useful purpose, and the end-results, though ankylosis occurred, were very good.

A practical difficulty lies in deciding upon the length of the period of probation, for in many cases of suppurative arthritis acute symptoms are not manifest until as late as the tenth day, and the fact that effusion into the joint is occurring may escape notice by the leakage of synovial fluid into the depth of an open wound near the joint. Many coincident conditions may be factors in producing pyrexia, increased pulse-rate, and other symptoms of toxic absorption. In some cases—necessarily not included in the foregoing list—the local signs, the symptoms, and the withdrawal of a synovial fluid rich in polynuclear leucocytes have prompted me to adopt the physiological method of treatment without delay, knowing that evidence of the existence of bacteria might require forty-eight hours to be reliable, the time necessary for incubation of organisms dilatory in growth on artificial culture media. In no case where the pathologist's report was subsequently negative for bacteria did contamination of either the stomata or the interior of the opened joint occur, and progress to free mobility was unhindered.

SUMMARY AND CONCLUSIONS.

1. All surgical methods of draining the knee-joint in suppurative arthritis have certain drawbacks.

2. The physiological method of treatment described above endeavours to provide : (*a*) A circulation of synovial fluid with maximum powers of resistance, in virtue of a free blood-supply to the affected joint ; (*b*) Free drainage for pus.

3. The practical requirements of the treatment are : (*a*) Free outlets for fluid from the joint ; (*b*) Active movements.

4. In about 50 per cent of the cases treated a useful mobile joint has been obtained.

5. In the absence of extensive bone injury—which necessarily negatives this treatment—provided the physiological method is established early, resolution is hastened and tracking is rare. Collections of pus in the popliteal space occur frequently.

6. The method is impracticable if its adoption be delayed until the establishment of the fulminating stage of suppurative arthritis.

TABLE OF CASES TREATED BY THE PHYSIOLOGICAL METHOD.

CASE NO.	ORGANISMS	BONE INJURY	EXTRA-ARTICULAR SUPPURATION	DAY WHEN ACTIVE MOVEMENTS BEGAN	RESULT
1	Staphylococcus Streptococcus (long chain)	Femur	*Thigh, aborted	11th day	Ankylosis
2	Staphylococcus Streptococcus (long chain)	Femur	*Thigh, aborted Popliteal	15th ,,	Ankylosis
3	Staphylococcus Streptococcus	Tibia and patella ..	*Thigh, aborted Popliteal	10th ,,	Ankylosis
4	Diphtheroids Streptococcus (short chain)	Femur	—	7th ,,	90° mobility
5	Staphylococcus Streptococcus	None	Popliteal ..	5th ,,	105° ,,
6	Staphylococcus Streptococcus	Femur	—	4th ,,	90° ,,
7	Staphylococcus Coliform bacillus	Tibia, femur, and patella	—	6th ,,	60° ,,
8	Staphylococcus Streptococcus (long chain)	Fibula	Popliteal ..	4th ,,	Amputation
9	Staphylococcus	Patella	Popliteal ..	5th ,,	Ankylosis
10	Staphylococcus Streptococcus	Femur	Popliteal ..	11th ,,	Ankylosis
11	Staphylococcus Coliform bacillus	Femur	2 in. up from external arthrotomy wound	10th ,,	Ankylosis
12	Staphylococcus	Tibia	Popliteal ..	6th ,,	Ankylosis
13	Staphylococcus Streptococcus	Patella	Suppurating hæmatoma of thigh	9th ,,	Ankylosis
14	Staphylococcus	None	—	7th ,,	Full mobility
15	Streptococcus Coliform bacillus	Femur	—	4th ,,	45° mobility
16	Staphylococcus Coliform bacillus	Patella	Popliteal ..	5th ,,	Ankylosis
17	Staphylococcus *B. Welchii*	Femur	—	5th ,,	Full mobility
18	*B. Welchii*	Patella	—	7th ,,	Full mobility
19	*B. Welchii*	Femur	—	3rd ,,	Full mobility
20	Streptococcus (long chain)	Tibia	Popliteal ..	4th ,,	Ankylosis
21	Staphylococcus	Femur	—	7th ,,	50° mobility
22	Staphylococcus	None	—	6th ,,	Full mobilitty
23	Streptococcus (long chain)	Femur	—	13th ,,	Ankylosis

* By this is meant that at the time of my original operation pus had extended through the suberural bursal reflection. No further tracking ensued.

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5 VEILLON, *Comptes Rendus de la Conférence Interalliée pour l'Etude des Plaies de Guerre*, 1917, March.
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8 CARREL, *Le Traitement des Plaies Infectées.*

WAR CONTRACTURES—LOCALIZED TETANUS, REFLEX DISORDER, OR HYSTERIA.

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Seale Hayne Military Hospital.

From an early date in the War there was much controversy as to the nature of the frequent cases in which contractures occur as a result of injuries to the soft parts of the limbs, with or without the bones and joints being involved. The contractures are generally discovered when the dressings and splints are removed, but they may be noticed directly after the infliction of the wound, or only develop gradually several weeks later.

The War Office Committee for the Study of Tetanus circulated questions as to the frequency of muscular contractures after injuries among the "principal surgeons in England, especially those whose practices are among the large industrial classes, where injuries in civil life are common." Answers were received from about eighty surgeons, only one of whom had ever seen such a sequel of a wound. The result of the inquiry is remarkable, for I have seen frequent cases of contracture following injury in civil life; and I have no doubt that if the questions had been sent to neurologists and orthopædic surgeons, very different answers would have been obtained. In the following case, for example, the man was rapidly cured by psychotherapy of a contracture of the hand, which had developed after amputation of a finger five years before he joined the Army.



Fig. 503.—Hysterical contracture of six years' duration following amputation of finger.

Hysterical contracture following amputation of a finger, of six years' duration, cured by psychotherapy in an hour.

Pte. W., age 26, had the third finger of his left hand amputated in April, 1912, for blood-poisoning. Following the operation, all the fingers of the hand became rigidly flexed (*Fig.* 503), but no treatment was given. He was admitted into the Army in April, 1917, in spite of his disability. He was employed on light work for the following eleven months, and was then admitted under us. He was treated by manipulation and persuasion, and in an hour there was complete relaxation of the fingers (*Fig.* 504). Next day, under further treatment by persuasion and re-education, movement in all the joints was obtained. At the end of three weeks his hand was quite strong, and he was able to use it for all ordinary purposes. (Major J. L. M. Symns.)



Fig. 504.—Same hand as *Fig.* 505 after an hour's treatment.

Localized Tetanus Theory.—Having received these answers, the Tetanus Committee came to the conclusion that the condition must be a new one, which had arisen as a result of some special circumstances arising in the present war, and they ascribed it to localized tetanus, which had never been recognized in man before, but which undoubtedly occurs now that the routine administration of prophylactic injections of antitetanic serum has caused generalized tetanus to become comparatively rare. Most of the speakers at the conjoint meeting of the Sections of Surgery and Neurology of the Royal Society of Medicine with the Tetanus Committee, held as recently as Feb. 14, 1918, to discuss "Muscle Contractures following Injury," appear to have believed that localized tetanus is the explanation in the majority of cases.

Until the present war the only form of localized tetanus which had been recognized was the so-called cephalic or head tetanus. A few cases had been recorded in which the spasms began in the injured limb and remained most severe in it after generalization occurred; but the first case of tetanus, in which the symptoms were strictly localized to one limb throughout the illness, was described in May, 1915, by Courtellement. Numerous observations on the subject have been published in France and England since that date, but even now many cases of localized tetanus probably escape recognition through want of familiarity with the condition.

Most cases of localized tetanus which occurred before the middle of 1915 must have been diagnosed as traumatic hysterical contracture, and five out of the nine cases I have seen were at first regarded as hysterical. On the other hand, the contractures in at least two cases which have been published as examples of local tetanus must really have been hysterical in origin, as they developed immediately after the wound was received, although it is impossible for tetanus to develop until the bacilli introduced in the wound have had time to produce the toxin, which has then to travel to the central nervous system before it can give rise to symptoms.

In the early stages the diagnosis between localized tetanus and hysterical spasm may be extremely difficult. If the contractures persist without abating for more than three or four weeks, and do not disappear completely at the end of six or eight weeks, they are probably hysterical, even if they were at first due to tetanus. Spasms which begin immediately after the wound is inflicted cannot be due to tetanus; they are generally reflex and protective in nature, but are often maintained after the first few hours or days by autosuggestion. A later onset is compatible with both tetanus and hysteria, and in both the extent of the contracture is often out of all proportion with the size of the wound. If the contracture persists in sleep, hysteria can be excluded. A general anæsthetic causes hysterical contractures to disappear more rapidly than tetanic contractures, which persist to some extent even under deep anæsthesia, although even the former may still be present after consciousness is lost. If the muscles are of a wooden and unvarying hardness, tetanus is almost certainly present. An increase in the size of the muscle, possibly due to obstruction of its lymphatics, without tenderness or subcutaneous œdema, is conclusive evidence in favour of local tetanus. The continued tonic contraction in tetanus is generally accompanied by spasmodic and more or less painful contractions, which are often brought on by external stimuli. When there is any doubt as to the diagnosis during the first week, the condition should be assumed to be local tetanus, as it is never possible to say whether generalization may not develop later. Early injections of antitetanic serum should prevent this, and they will do no harm if the spasms are not really due to tetanus. After contractures have persisted for a month, they should be regarded as wholly or in part hysterical in origin, and psychotherapy should be employed without further delay.

Reflex Theory.—Babinski and Froment believe that many of the contractures which have hitherto been regarded as hysterical, or due to some obscure condition such as an ascending neuritis, as believed by Tinel, are really reflex in origin. They have summarized their views in the second section of their book published in 1917 on *Hystérie-Pithiatisme et Troubles Nerveux d'Ordre Réflexe en Neurologie de Guerre*. This theory at first seems to offer a satisfactory explanation of many cases, the nature of which had hitherto remained obscure; but a critical investigation of the subject has convinced us that such reflex conditions never occur.

Babinski and Froment admit that reflex symptoms resemble hysterical symptoms in being quite out of proportion with the often trivial injury which gave rise to them, but state that they differ in being entirely unaffected by psychotherapy and in certain clinical features. The former distinction I have already criticized, as in our experience rapid recovery always follows persuasion and re-education. The clinical features, which were believed by Babinski and Froment to exclude the possibility of hysteria, are discussed in a later section, where they are shown to be secondary to the impaired venous and lymphatic circulation, caused by the disuse resulting from hysterical paralysis and contracture.

There is no doubt that reflex contraction of the neighbouring muscles is not uncommon

immediately after a wound is inflicted, the reflex being protective in nature, just as is the reflex contraction of the abdominal muscles in acute appendicitis or after perforation of a gastric ulcer. When, however, the symptom persists after the wound has healed, it is no longer due to any reflex action, but is the result of suggestion ; the contracture is thus primarily reflex and subsequently hysterical.

Hysteria.—Our own observations have led us to the conclusion that hysteria is invariably the cause in chronic cases, and that even when localized tetanus or a reflex spasm is present at the onset, any symptoms which persist are due to perpetuation by suggestion ; they are thus eventually hysterical.

The matter is by no means of merely academic interest. If the contracture is due to localized tetanus, the proper treatment would be by injections of antitetanic serum. If the reflex theory of Babinski and Froment is correct, the patients can only be very slowly cured after months of treatment by physical methods. If, however, the contractures are hysterical in origin, they should be curable at a single sitting by psychotherapy.

When hysterical contractures are erroneously diagnosed as being due to localized tetanus or reflex action, the correct treatment will not be undertaken. Thus Wilfred



FIG. 505.—Hysterical contracture of hand of fifteen months' duration, cured by suggestion.

Harris, who apparently regards the condition as frequently due to tetanus, states that "these cases are most resistant and difficult to treat." He has tried to straighten the fingers and put them into splints under an anæsthetic, but without success. In the same way the popularization of the idea of reflex symptoms, by the publication of Babinski and Froment's book, and its translation into English, is likely to lead to hysterical conditions being diagnosed as reflex, with the result that they will not receive the benefit of psychotherapy, which would otherwise have cured them. It is a curious fact that Babinski, who more than any other neurologist has demonstrated the important part taken by suggestion in the origin of hysterical symptoms, and has shown how they can be cured by suggestion, should himself have become a victim of suggestion ; for, having made up his mind that these contractures are reflex, and therefore not amenable to psychotherapy, he has failed to cure them by psychotherapy, and has described this failure as one of the most characteristic features of the condition.

The following case, which was the first one I saw after reading Babinski and Froment's book, illustrates how an implicit belief in their teaching would have led us to neglect psychotherapy, without which the patient could not have been cured.

Hysterical contracture and paralysis of fifteen months' duration, at first supposed to be reflex,' cured by suggestion.

Pte. W., age 21, received a slight wound in the hand in May, 1916. When the dressings were removed, his hand was found to be fixed with the fingers semiflexed and the thumb adducted. Movements of the elbow and wrist were normal, but he could make no movements with the fingers or thumb. The wound soon healed, but the condition of the hand persisted in spite of massage and electricity. It had been supposed that the contracture was due to adhesions involving the tendons and palmar fascia. I first saw him in August, 1917, fifteen months after the wound was received. No improvement had occurred, the fingers and thumb being still flexed (*Fig.* 505); but it was found that the contracture could be slowly overcome by force. When a voluntary effort was made to move the fingers or thumb, the affected muscles were seen to contract, but no movements resulted, as the muscles opposing the desired movement also contracted instead of relaxing. There was no atrophy, and the electrical reactions were normal. The hand was swollen; it was red when the room was warm, and blue when it was cold, a considerable difference in temperature between the two hands being present always; excessive sweating also occurred on the palm of the affected hand.

The condition would have at once been diagnosed as hysterical, had it not been that a recent study of Babinski and Froment's work on reflex paralysis and contracture led to the suggestion that this was an example of such a reflex condition, as the position of the hand was identical with that shown in one of the figures in their book, and œdema, vasomotor changes, and excessive sweating—which, according to them, never occur in hysteria but are common in reflex disorders—were present.

As I wished to see how much relaxation occurred under anæsthesia, ether was given. The contracture relaxed more slowly than would have been expected in hysteria, this seeming at first to confirm the diagnosis of a reflex condition; but as I was still doubtful as to whether the condition might not be hysterical, I tried the effect of vigorous suggestion with the aid of electricity as the patient was coming round. With this treatment the muscles relaxed and all movements became possible. During the next few days treatment by re-education was continued, with the result that ten days later the patient was able to use his hand for all ordinary purposes. Simultaneously with the disappearance of the contracture and paralysis, the œdema, sweating, and vasomotor disturbances completely disappeared.

PATHOGENESIS.

The posture in hysterical contractures is identical with that which happened to exist at the time the contractures developed, and is in many cases that which was assumed immediately after the injury. Thus, if one or more peripheral nerves were damaged, the position corresponds with what would result from paralysis, or occasionally from irritation, of these nerves. In such cases, when the nerve recovers from the effect of the injury, which may be within a few hours if the latter is nothing more than slight concussion, or may be weeks or months if it is more serious, the abnormal posture and the inability to move are maintained as a result of suggestion.

In other cases the injury may lead to reflex spasm of the neighbouring muscles and inhibition of movement of the whole limb, which is protective in nature, but which rapidly disappears as the condition of the wound improves. Apart from this reflex action, the patient more or less subconsciously assumes the position which gives most relief to the pain caused by his injury; he keeps the affected segment of the limb rigidly in this position, and at the same time he often abstains from moving the limb as a whole, as this too would cause pain. Both the reflex and semiconscious local spasm and general inhibition are liable to be perpetuated by autosuggestion when the condition of the wound improves and the pain diminishes, the initial reflex and voluntary conditions merging insensibly into hysterical spasm and paralysis. The patient does not realize that the absence of voluntary effort on his part had the object of saving him from pain, but believes that it was due to 'paralysis'—the direct result of his injury.

In some cases the injury itself places the limb in some abnormal position, and this is maintained owing to the pain, which the patient experiences when he tries to correct it, and to the reflex and voluntary spasm which oppose the efforts of the surgeon to replace it. This is particularly well seen in the hysterical contracture causing talipes equinovarus

(*Fig.* 506) after the foot has been twisted into this position by an accident, whether this results in a simple sprain, tearing of ligaments, or a fracture.

Occasionally an hysterical contracture develops as a sequel of local tetanus. In such cases the posture is that caused by the contraction of the muscles, which are supplied by the anterior cornu cells of the spinal cord in the neighbourhood of the point of entry of the afferent nerve fibres connected with the parts immediately adjoining the wound, from which the tetanus toxin is absorbed. When at the end of three or four weeks the tetanic spasm gradually disappears, the contracture may persist as an hysterical condition. Apart from the history, this origin should always be suspected when the spasm involves a group of muscles or the whole or a segment of a single muscle, which could hardly be thrown into action alone by voluntary effort. Thus, in one such case the knee was fixed in a position of extension by spasm of the sartorius; and in two others the knee was flexed and the foot plantar-flexed by a localized spasm of a small segment of the hamstrings and the calf muscles respectively. Contractures of this sort could not be imitated voluntarily, but the patient had become accustomed to them whilst the tetanus lasted, and the habit thus learnt was perpetuated without alteration when the tetanic spasm was gradually replaced by the hysterical contracture.



FIG. 506. Hysterical talipes equinovarus following a sprain, cured in half an hour after persisting for nine months.

In many cases the posture is that in which the surgeon fixed the limb by means of splints or bandages when it was first dressed. The patient becomes so accustomed to the immobility of the joint, that when the splint or bandage is removed, he fails to realize that there is nothing to prevent the return of the normal functional activity. He makes a feeble effort to bend the joint, finds that it gives rise to pain without any obvious movement resulting, and gives up the attempt in despair, reconciling himself to the notion that the joint has become fixed as a result of the operation, and that no voluntary effort that he can make will have any effect upon it. A little manipulation, accompanied by a few words of explanation, could at this stage dispel the idea in five minutes, and months of disability would be saved. But too often the after-treatment is neglected, or the patient is ordered massage and perhaps diathermy and kataphoresis, which are given systematically by sympathetic nurses, with the result that the patient becomes more convinced than ever that there is something seriously the matter, and that he will only get well with prolonged treatment, if indeed he will get well at all.

Hysterical contracture following an operation, cured by persuasion in five minutes.

Pte. H., age 30, had the internal semilunar cartilage of his right knee removed on Feb. 12, 1918. We were asked to see him on April 5, as he could still only walk with the aid of sticks, and was afraid to put any weight on his leg, his knee being kept quite stiff. By means of simple persuasion, which took only five minutes, he was able to walk quite normally, no limp being perceptible. He walked back to his ward, leaving his sticks behind. He had not the complete range of flexion that he had in the other leg: but he had quite enough to enable him to walk and run and to become once more an efficient soldier.

In cases of this kind the posture may alter from time to time if the splint is changed. Thus, a man was wounded in the wrist, and his hand was bandaged with the fingers tightly clenched. Some weeks later the surgeon found that the hand had become

contracted in this position. Under an anæsthetic the fingers were now fixed on a splint in a position of extreme hyperextension. Six months later his hand was still rigidly fixed in the new position. He came under the care of Captain A. Robin, who rapidly cured him by psychotherapy. As the posture is artificially produced by the use of splints, it may sometimes be one which cannot be imitated voluntarily ; but it is none the less hysterical, the patient having been trained to maintain the position whilst the splint was in position.

In all these conditions the development of the hysterical contracture and associated paralysis is due to the fact that the patient fails to realize that there is no reason why the spasm should not relax and the power of movement return when the primary factor—nerve injury, protective reflex, conscious or subconscious antalgic spasm and inhibition of movement, localized tetanus, or fixation by splints or bandages—is no longer operative. The patient regards the contracture and inability to move as a direct result of his injury, and naturally ignores the intermediate cause, such as the pain or tetanus. If it had been pointed out to him, when the pain was disappearing, that his incapacity was due to the pain and only indirectly to the injury, and that there was therefore no longer any reason why it should be maintained, he would have made the necessary effort, and the hysterical condition would never have developed. But not having been told this, and perhaps having been ordered treatment with massage or electricity at a stage when such treatment could have been of no real use, as recovery from any organic injury which may have been present at first was now more or less complete, the idea of incapacity was confirmed in his mind, and the original autosuggestion was fortified by the unconscious heterosuggestion of the doctor and the masseuse, with the result that the contracture and paralysis were perpetuated as hysterical conditions after the primary cause had disappeared.

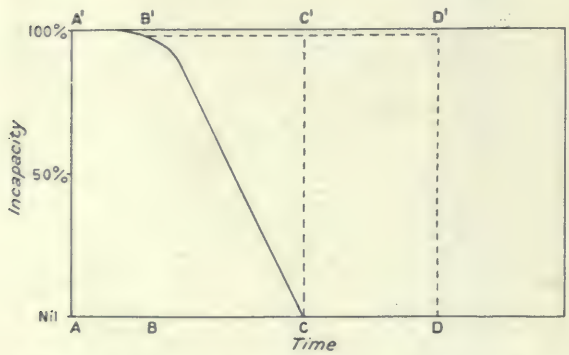


Diagram I.—Hysterical contracture following painful wound. (The dotted lines in this and other diagrams represent the hysterical incapacity.

The development of the hysterical contracture and paralysis is shown in *Diagrams I* to *III*, the vertical representing the degree of spasm and paralysis, and the horizontal the time elapsed since the onset.

In *Diagram I* the incapacity due to an antalgic protective reflex and conscious and subconscious antalgic immobility and rigidity is at first complete (AA'). It continues to be so for a certain period, and then at the time B it begins rapidly to diminish, and completely disappears when the wound is healed at the moment C. Meanwhile, however, the immobility and spasm may persist owing to auto- and heterosuggestion, and the functional condition may show no improvement at the time C', when CC' represents the incapacity, which is now entirely hysterical. At this moment, or any subsequent moment such as D, a cure can be obtained by psychotherapy, the rapid recovery being represented by the line DD'.

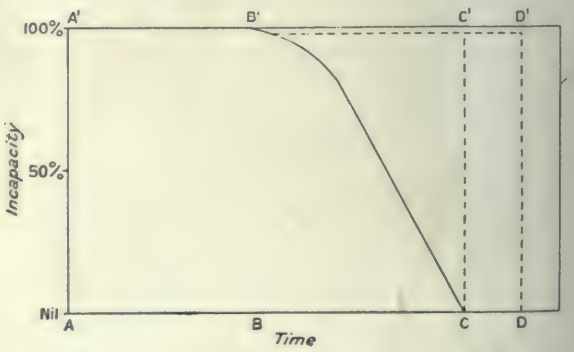


Diagram II.—Hysterical contracture following local tetanus.

In *Diagram II* the condition in localized tetanus is represented in the same way, but here the period AB is much more prolonged.

In *Diagram III* the condition which may result from the prolonged use of a splint is represented; but, in this case, the moment it is removed, all the non-hysterical immobility caused by the splint of course disappears, this being represented by the vertical line BB′, instead of by the sloping line BC′ of *Diagrams I and II*.

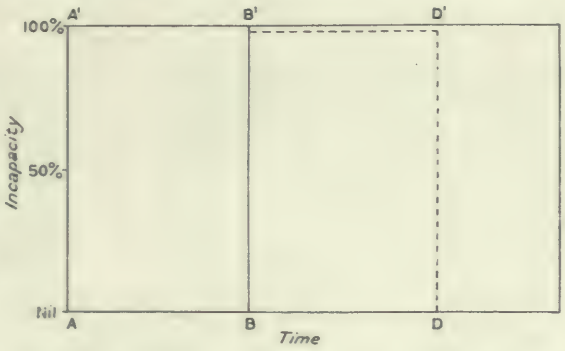


Diagram III.—Hysterical contracture following application of splint.

From what has been said above, it is clear that contractures are always associated with more or less paralysis; but the reverse is not the case, as uncomplicated hysterical flaccid paralysis is not uncommon. In many cases the paralysis is more extensive than the contracture, a contracture of the hand, for example, being sometimes accompanied by paralysis of the whole arm.

ETIOLOGY.

Hysterical contractures and paralysis may result from injuries to the soft parts of the limb, with or without the bones and joints being involved. The commonest cause is a wound of the hand, foot, forearm, or leg, the symptoms generally developing below and above the injury as well as in its immediate neighbourhood. In many cases no nerve is involved, but in others temporary concussion of one or more peripheral nerves or of the brachial plexus may have occurred, or they may have received some actual injury of a recoverable nature. The severity of the symptoms does not vary with the degree of infection or the extent of the injury, which is often trivial. They are very rarely associated with severe wounds, but we have seen a considerable number of cases in which hysterical contracture and paralysis has occurred in the hand after one finger has been amputated (*Figs.* 507, 508), and less frequently in the foot after the amputation of a toe.



FIG. 507.—Hysterical contracture of hand persisting for nine months after amputation of second finger. (Capt. A. Robin.)



FIG. 508.—Same hand as *Fig.* 507, cured after half an hour's psychotherapy.

In other cases a severe injury to one finger has resulted in contracture affecting the whole hand (*Figs.* 509, 510). We have observed contractures and paralysis of exactly the same nature in the absence of actual wounds—as, for example, in fractures, dislocations, sprains, and contusions. In a few cases the symptoms have followed some minor opera-

tion, such as for a ganglion of the wrist, varicose veins in the leg, or an abscess of the arm or leg. In one case it followed plating a fractured tibia; three cases followed superficial burns; two followed cellulitis; and one case of flaccid paralysis of the arm followed anti-



FIG. 509.—Hysterical contracture following gunshot wound of hand with shortening of middle metacarpal. (Capt. C. H. Ripman.)



FIG. 510.—Same hand as *Fig.* 509, cured in five minutes after persisting for thirteen months.

smallpox vaccination. Several cases of hysterical contracture and paralysis of one or both legs followed trench foot; and we have seen seven cases in which the hysterical contracture appeared to be the sequel of localized tetanus.

Hysterical monoplegia of seven weeks' duration following vaccination, cured in three-quarters of an hour.

Rfmn. D., age 21, was admitted on Aug. 12 with paralysis of the left arm. He states that he was vaccinated on May 30, and on June 28, when at squad drill, he found that his left arm had suddenly become powerless. The limb was hanging useless by his side, and the hand and lower four inches of the forearm were blue and cold, the palm being mottled and purple. Persuasion for a quarter of an hour produced movements of the arm; in half an hour the colour and temperature were normal; and all movements of the limb, including the fingers, were perfect after three-quarters of an hour, though the hand-grip was not perfect until the next day. (Capt. G. McGregor.)

Hysterical rigidity of knee of three months' duration following superficial cellulitis, cured in half an hour.

Pte. S., on Oct. 4, 1917, developed a large septic sore on the outer side of his right knee, which was incised a week later, a back splint being applied. The latter was removed on Nov. 7, when the knee was found to be rigidly extended. On Dec. 28 free movements were obtained under an anæsthetic, but on the patient coming round, the knee remained fixed as stiffly as before. There was no improvement under massage, and on Jan. 28, 1918, he was sent to us as an out-patient. Within half an hour, by means of explanation, manipulation, and persuasion, 30° flexion was obtained. He was instructed to perform exercises, but when seen again on Feb. 18 very little further improvement had occurred. Another half-hour of similar treatment resulted in full flexion being obtained, and the patient was discharged a few days later. (Major J. L. M. Symns.)

Hysterical 'main d'accoucheur' and anæsthesia following concussion of median nerve by gunshot wound of the forearm, cured by manipulation and persuasion in ten minutes, after persisting for eight months.

Sergt. M. was wounded in the right forearm on April 10, 1917, a compound fracture of the middle third of the radius being produced. When the splints were removed three weeks later, his hand showed a typical 'main d'accoucheur' deformity, the fingers being rigidly extended and pressed together. Total anæsthesia was present in the area supplied by the median nerve. As no improvement had occurred by November, an operation was performed, and the tendons and median nerve were freed from adhesions. This, however, aggravated the contracture, so he was transferred to us on Dec. 21, 1917.

Well-marked vasomotor disturbances, excessive sweating, and considerable atrophy of the soft tissues and nails were present. On the day of admission the hand was continuously but painlessly manipulated, the patient being persuaded at the same time that it would rapidly relax. In ten minutes complete relaxation was obtained and the deformity had disappeared. The fingers, which had not been moved voluntarily for eight months, could now move normally, but an area of total anæsthesia was still present. The anæsthesia was doubtless originally organic in origin, but as it now extended considerably beyond the area supplied by the median nerve, we thought that it must be hysterical. Suggestion with the aid of faradism, for a few minutes on two occasions, resulted in its complete disappearance. With the return of movement the vaso-

motor and secretory disturbances disappeared. A slight degree of wasting of the small muscles of the hand was now found to be present, but otherwise the hand was normal in every way. The patient was kept under observation for three weeks, and as there was now no incapacity he returned to duty.

VARIETY OF POSTURES.

In most cases a single segment of a limb is involved, the hand and foot being most frequently concerned. Very often, however, the whole or greater part of the limb is affected, but in such cases the contracture and paralysis is most severe in the immediate neighbourhood of the injury, although in rare instances the whole limb is completely paralyzed and rigid.

Upper Limb.—Hysterical contracture and paralysis of the hand give rise to three common types of posture. The fingers may be extended, in which case they are generally also adducted towards the middle finger, a 'main d'accoucheur' resulting (*Figs.* 511, 512, 513); in the case shown in *Fig.* 514, the fingers were abducted as well as extended. The other extreme is for the fingers to be tightly clenched into the palm of the hand; all the fingers may be involved (*Figs.* 503, 515), or only two or three (*Fig.* 516), in which case one finger may occupy an intermediate position (*Fig.* 517); in these cases the skin often becomes sodden with sweat, owing to the impossibility of evaporation and the difficulty in washing; in one case, in which the position had been maintained for two and a half years, the nails of three fingers were found to have produced a depression about a quarter of an inch deep into the palm of the hand (*Figs.* 518, 519). In the third variety, the hand takes up an intermediate position very similar to that assumed normally at rest.



FIG. 511. Hysterical 'main d'accoucheur' following wound of forearm. (Capt. R. G. Gordon.)



FIG. 512.—Same hand as *Fig.* 511, cured in one and a half hours after lasting eighteen months.

In the extended and clenched positions the paralysis is always accompanied by more or less contracture; the intermediate position is that generally assumed in flaccid paralysis

(*Fig.* 520), but it may also be associated with contracture (see *Fig.* 505), though this is rarely severe. In most cases all the fingers are affected, but sometimes, especially when



FIG. 513.—Hysterical 'main d'accoucheur' following wound of the hand, cured in five minutes after persisting for ten months. (Capt. A. W. Gill.)



FIG. 514.—Hysterical contracture following amputation of index finger, cured in one hour after persisting for twelve months. (Capt. A. Robin.)

the condition has followed an injury of the hand or wrist, only those fingers most directly involved by the wound are implicated, the others being either normal or only comparatively slightly involved. Occasionally the fingers are in a position of extreme hyperextension, which may be so marked that it suggests that the condition cannot be hysterical in origin (*Fig.* 521). In most cases of this sort, however, it is found that a patient has always been able to hyperextend his fingers, and a similar, though rarely so well-marked, hyperextension can be produced by voluntary action in the other hand.



FIG. 515.—Hysterical contracture of fingers following wound of right upper arm, cured by psychotherapy in one hour after persisting for sixteen months. (Capt. A. W. Gill.)

When the wrist is involved, it is commonly in an intermediate position or flexed; in rare cases it may be fixed even to the extent found in an organic dropped wrist due to complete musculo-spiral paralysis (*Fig* 522). Hyperextension of the wrist is uncommon.

The hand is very frequently in a position midway between supination and pronation. When the contracture is incomplete, it is almost always possible to obtain greater movement in the direction of pronation than supination, inability to supinate the hand completely being very common.



FIG. 516.—Hysterical contracture of three fingers persisting for nine months after wound of wrist, cured within an hour by psychotherapy.

When the elbow is involved, it is almost invariably flexed, but I have seen two cases of extreme extension. The flexion is generally such as would correspond with the position of the arm when held in a sling.



FIG. 517.—Hysterical contractures of fingers of twenty months' duration following gunshot wound of forearm, cured in an hour by psychotherapy. (Capt. S. H. Wilkinson.)



FIG. 518.—Hysterical contracture of hand persisting thirty-five months after wound near elbow. (Capt. C. H. Ripman.)



FIG. 519.—Same hand as *Fig.* 518 after half an hour's treatment, showing depressions formed in palm by pressure of nails.

When the shoulder is affected, the arm is generally held rigidly to the side. In incomplete cases, and when recovery is taking place spontaneously, it is often found that



FIG. 520.—Hysterical flaccid paralysis of left hand following wound in neighbourhood of brachial plexus, cured in an hour after persisting for eleven months. Both hands of the patient are shown, the remainder of the figure having been removed.



FIG. 521.—Hysterical contracture of left hand with hyperextension of fingers following a wound of forearm, cured in half an hour after persisting for seven months.

the elbow can be raised to the level of the shoulder, but it is impossible to raise it any further (*Figs.* 523, 524, 525).

Lower Limb.—In rare cases the toes alone are affected. One patient, who had been wounded in the thigh, developed a persistent flexor contracture of his toes, which disappeared as a result of psychotherapy after it had persisted for nine months.

In the commonest variety of hysterical contracture and paralysis involving the leg, the foot is extended in a position of talipes equinus. This is often associated with varus, which may be present alone (*Fig.* 526). In some cases a very extreme degree of talipes equinovarus is present (see *Fig.* 506). These conditions may be due to simple flaccid paralysis, but there is generally some degree of rigidity, and in many cases the contracture is so extreme that not the slightest movements can be obtained in the joints by ordinary means.



FIG. 522.—Hysterical dropped wrist following wound of wrist, improved in an hour, cured in three days, after persisting for twenty-four months.

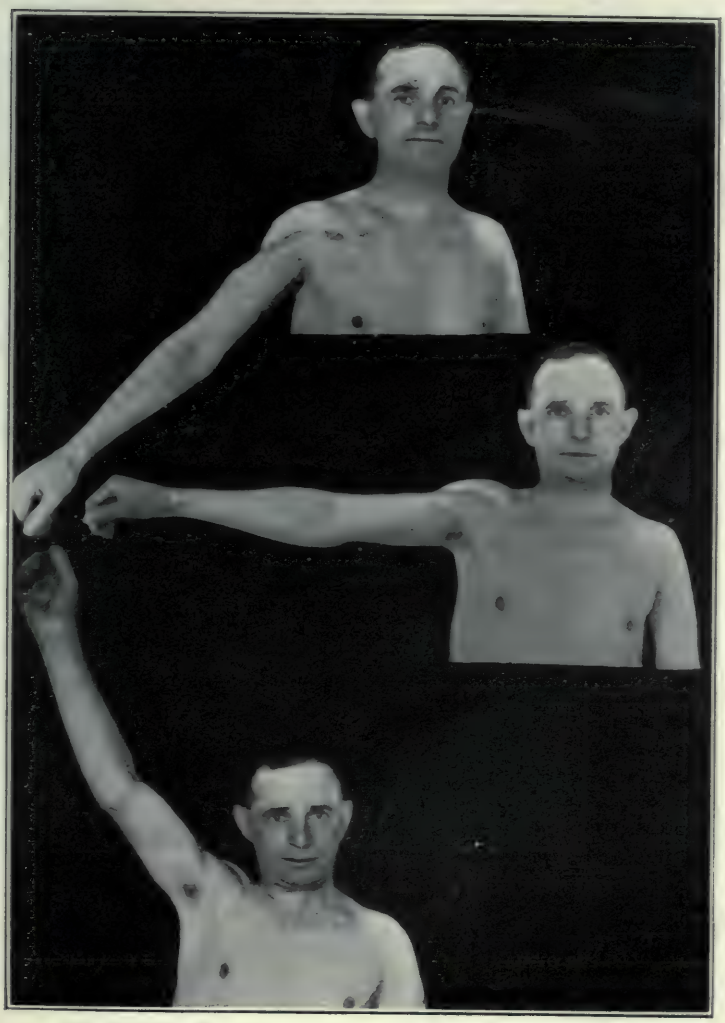


FIG. 523.—Hysterical contracture of shoulder muscles following wound in pectoral region.

FIG. 524.—Same case as *Fig.* 523 with partial recovery as the result of a quarter of an hour's treatment, after persisting for eighteen months.

FIG. 525.—Same case as *Fig.* 523, complete recovery with further psychotherapy on two following days.

Hysterical rigid talipes with paraplegia, tremor, and stammer of fourteen months' duration, cured in two days.

Sergt.-Major P., age 32, was blown up in December, 1916, and remained unconscious for some days. He was paraplegic, stammered badly, and had a generalized tremor when admitted to a provincial hospital, where he remained for three months. He was then transferred to a hospital in London, where he remained for nine months. He was treated with massage and electricity, but very little improvement occurred. A piece of bone was removed from the foot in October in order to correct this deformity, but no improvement resulted. At Christmas, 1917, he was sent to a convalescent hospital, from which he was transferred to us on Feb. 14, 1918. He stammered badly, and had a severe tremor involving both legs, which increased with every voluntary movement, so that he was unable to stand, and could only walk a few unsteady steps with the aid of sticks, when further progress was prevented by the violence of the tremor. As no signs of organic disease were found, I told him that the treatment he would have the following day would cure him, and the presence in his ward of three men who had recently been cured of paraplegia helped to convince him that this was true. By 5 p.m. the next day, as a result of persuasion and re-education, he could talk slowly without any stammer, and he walked a quarter of a mile with a gait which was normal except for a limp due to the talipes equinovarus.



FIG. 526.—Hysterical talipes varus of thirteen months' duration following wound of ankle, cured in a few minutes. (Capt. S. H. Wilkinson.)

As I could not at first overcome the deformity of his left foot (*Fig.* 527) by manipulation, I thought it might be due to some organic injury, especially as an operation had been performed upon it after a radiographic examination in London. Moreover it was colder than the right foot, and was always wet with sweat, whilst the right foot was dry, evidence which would be accepted by Babinski as excluding hysteria and suggesting a reflex origin. More vigorous manipulation, however, two days later, continued for an hour and a half, resulted in complete disappearance of the deformity (*Fig.* 528), and the patient was now able to walk without any limp. It is obvious, therefore, that the talipes, like the paraplegia and stammer, was hysterical in origin.



FIG. 527.—Hysterical talipes equinus of fourteen months' duration.

The knee is frequently involved, extension and flexion being about equally common. Extreme flexion is rare, but rigid fixation in a position of semiflexion is often seen. Contractures in the position of extension are frequently so extreme that not the slightest movement can be obtained actively or passively until relaxation is produced by vigorous psychotherapy.

Hysterical stiff joint following gunshot wound of the knee, cured by persuasion.

Sergt. W., age 23, sustained a gunshot wound on the outer side of his left knee on Jan. 16, 1918, which penetrated the joint. At the casualty clearing station the foreign body was removed, the joint was washed out, and the capsule closed. He reached a hospital in Scotland on Jan. 30,

and on Feb. 20 he was allowed to get up, but the limb was still in a splint, and he had to use crutches. Four months later, according to his documents, adhesions of the knee-joint were broken down under an anæsthetic, and he was sent to a Command Depôt. He was admitted to Seale Hayne Hospital on Aug. 20, walking with the aid of a stick, with a very bad limp owing to inability to bend his left knee. Except for the scar of the incision on the outer side of the joint, the knee appeared normal, but he could only flex it to about 120°. The stick was taken away, and with persuasion and re-education for half an hour complete flexion was obtained, and he walked with only a slight limp. The next day he was able to go up and downstairs and walk on the level without a limp. (Capt. G. McGregor.)



Fig. 528.—Same foot as *Fig.* 527, cured after one and a half hours' treatment.

When the hip is involved, the limb is generally in a position of slight flexion, but rigid extension is sometimes seen. Adduction or abduction, and eversion or inversion, may be present.

Hysterical flaccid foot-drop, with inversion of the leg, following a gunshot wound of the right thigh a year before; rapid recovery with persuasion.

L.-Cpl. F., age 23, was wounded by shrapnel in the outer side of the thigh on May 11, 1917. A counter-opening was made, and a piece of metal removed. He began to get about on crutches in August, 1917, but always with his foot dropped and his leg turned inwards. On his medical case-sheet a specialist reports "there was some involvement of the right sciatic nerve." He was transferred to us on May 11, 1918, with a spring attached to his boot to keep his foot up, and he could only get about with difficulty with the aid of sticks. It was explained to him that, having held his leg so long turned inwards and with his foot down, he had forgotten how to use his muscles. With simple persuasion and very little re-education he was able to walk quite well. At the end of four days he was put on horseman's work and physical drill, as he walked quite normally except for a slight tendency to allow his knee to turn inwards. With this exception he is now quite fit. (Capt. S. H. Wilkinson.)

Trunk.—A wound of the back may give rise to an hysterical spinal deformity.

Hysterical kyphosis, associated with hysterical curvature in a horizontal plane, following a wound of the back.

Pte. B. was wounded on March 21, 1918. On admission in August, he had a superficial scar, three inches long, running diagonally across his back opposite the third dorsal vertebra. He showed very marked kyphosis, which produced two deep horizontal folds across his epigastrium, below which the abdomen was round and prominent. His chest was also hollow from side to side with very marked prominence of the points of his shoulders. He breathed very badly, with no abdominal movement, and very little expansion of the lower part of his thorax. He looked so pigeon-breasted, that the deformity was considered by some observers to be organic and due to adenoids, though he himself said he was absolutely straight until he was wounded. Unlike the majority of cases of hysterical spinal curvature,* the curvature did not disappear on lying down. But, with persuasion, his body was gradually straightened out, his shoulders being pressed back until both the kyphosis and the side-to-side curvature, together with the hollowing of his chest, had disappeared. After prolonged persuasion he was able to move freely, and the depression of his epigastrium and the prominence of his abdomen with the horizontal furrows across his epigastrium disappeared. Three weeks later, being quite fit, he was sent back to duty. (Capt. C. H. Ripman.)

CHANGES SECONDARY TO DEFICIENT CIRCULATION.

The normal circulation through a limb depends upon its active movements, the afferent nerve fibres from the muscles probably giving rise to localized reflex vasodilatation. If

* A. F. Hurst: The Bent Back of Soldiers, *Seale Hayne Neurological Studies*, 1919, i. 60.

for any reason the arm is not moved in cold weather, the hand becomes shrivelled, white or blue, numb, painful, and stiff. These well-recognized changes disappear at once with active exercise and on warming the limb, both of which restore the circulation. The tendency to disturbances of this kind is much greater in people with a poor circulation than in those with a naturally good circulation. The former class know by experience that they must keep their fingers constantly moving in cold weather in order to avoid getting numb.

It is thus natural for the immobility caused by paralysis or contracture of a limb, whether organic or hysterical, to result in deficient circulation and the same secondary changes. As, however, the paralysis is continuous, whereas the physiological inactivity referred to only lasts for a few minutes or at most for a few hours at a time, the secondary results are likely to become much more profound, especially in individuals with a poor circulation. The deficient circulation is generally congenital, but in soldiers it is often acquired or aggravated as a result of exposure. Thus, in all cases in which circulatory complications are severe, the circulation in the normal hand is also feeble. The limb, especially its peripheral part, becomes cold and white or blue, and the diminished blood-supply results in a diminution in the volume of the hand, except in the cases in which œdema develops. Pressure on the skin with a finger is followed by a very slow return of blood to the part rendered anæmic.

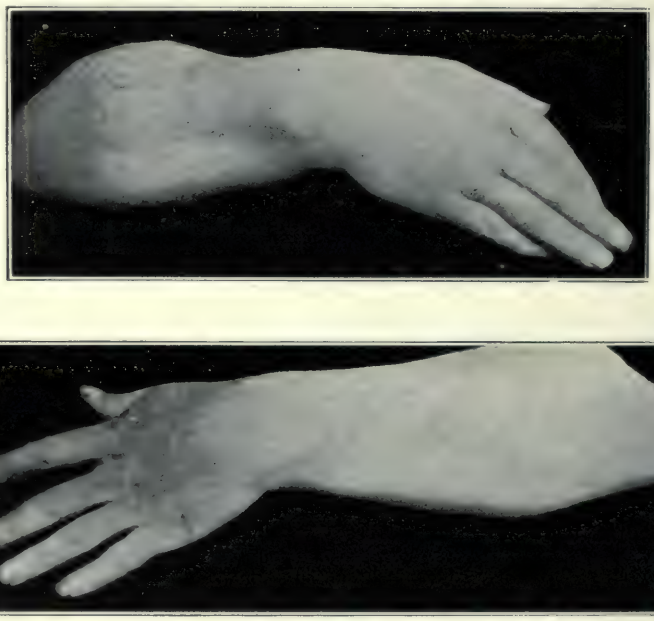


FIG. 529.—Hysterical contracture of right hand of fourteen months' duration, associated with severe œdema, cured in two hours. (Capt. A. W. Gill.)

When the venous and lymphatic stasis is very marked, and the paralysis absolutely complete, œdema may occur, especially if the paralysis is accompanied by contracture in a position in which the veins and lymphatics are obstructed by the rigid muscles. The œdema is sometimes very considerable, and may give rise to the impression that there has been some injury of the blood-vessels (*Fig.* 529). This, however, is not the case, for with the return of voluntary movement the œdema disappears in the course of a few days as the circulation becomes once again normal.

The deficient circulation results in changes in the physiological properties of the

paralyzed muscles, even if the paralysis is entirely hysterical. Babinski and Froment have shown that in these conditions the muscles respond with abnormal slowness to galvanic stimulation. They proved that this is not due to permanent changes in the muscles, by demonstrating that the response returns to normal when the limb is warmed; and we have observed that this also occurs directly recovery takes place as a result of psychotherapy, when the restoration of active movements gives rise to improvement in the circulation. Babinski and Froment also found that the muscles, and sometimes the nerves, are abnormally irritable to mechanical stimulation, the response being unusually prolonged; in some cases these signs are only obvious when muscular relaxation has been produced by a general anæsthetic. Babinski and Froment observed that when the leg is involved, the ankle-jerk may disappear or be weaker than on the normal side, returning to normal on warming. This phenomenon is clearly due to changes in the muscles, analagous to those which give rise to the abnormal reactions to electrical and mechanical stimulation. The other deep reflexes are often increased, this being most obvious when the contracture is partially overcome under light anæsthesia; the changes are probably due to the increased tonicity of the muscles, which persists until anæsthesia is very profound.

More or less stiffness of the joints is generally present in cases of long standing, even in the absence of any muscular spasm. This may be so extreme that not the slightest movement is possible. It is most obvious in the joints of the hand, particularly at the metacarpophalangeal articulations. It has often been regarded as due to some organic change, as it is very well seen in cases of organic paralysis following injuries to peripheral nerves. In such cases, so-called adhesions are often broken down under an anæsthetic, actual tearing being heard, and this is often followed by effusion round the joint. This has not unnaturally been regarded as evidence of organic change; but in all hysterical cases, and, I believe, in cases of organic paralysis, the stiffness is not really due to any permanent organic alteration in the tissues. A considerable amount of relaxation occurs when the circulation is improved by immersion in hot water, and particularly by such means as radiant heat and whirlpool baths. In hysterical cases, even of many months' duration, directly the patient has been taught to contract his muscles and to relax any spasm which is present, the return of movement so improves the circulation, that often in the course of a few minutes the condition of the joints and surrounding tissues returns to normal. As the condition of the joints is exactly similar to what is seen in organic paralysis, I feel sure that in the latter case also the condition is secondary to the deficient circulation; and if instantaneous recovery from the paralysis were possible, the joints would return to their normal condition without any manipulation or breaking down of adhesions being required. As the stiffness is due to circulatory disturbances, and not to any muscular spasm, whether hysterical in origin or not, it naturally persists under an anæsthetic; and when the joint is forcibly moved, the surrounding structures which are torn are not abnormal fibrous tissue, but simply the normal periarticular tissue, which is temporarily in an abnormal condition owing to the deficient circulation. The injury to the normal tissues naturally results in effusion. This is a point of the greatest importance, as it follows that the apparent tearing down of adhesions and production of inflammatory reaction does not necessarily mean that the condition is organic. When gas is used, or some other anæsthetic under which muscular relaxation is incomplete, any hysterical contracture which is present may also help to prevent free movement of the joint, as such a contracture, being quite independent of consciousness, only disappears under deep anæsthesia. Violent movements with incomplete anæsthesia may thus result in tearing of contracted but otherwise normal muscle fibres as well as of normal fibrous tissue.

By accurate measurement with a sphygmomanometer, Babinski and Froment found that the amplitude of the pulsation of the arteries in the affected limb is greatly diminished compared with that on the normal side. They found that this inequality disappears on warming, and Roussy and his colleagues, using exactly the same methods, noted its disappearance when the paralysis and contracture are cured by psychotherapy, proving that it is simply a result of the deficient activity of the limb.

Babinski and Froment found that the plantar reflex on the affected leg disappears,

but reappears on warming the foot. They also describe some indefinite anæsthesia in the peripheral part of the limb, and the patient may complain of a varying degree of pain. These phenomena are additional results of the deficient circulation, being of exactly the same nature as the numbness, pain, and loss of plantar reflex observed in normal people, especially those with a poor circulation, if the limb is cold or 'goes dead' in cold weather. Only if the anæsthesia is perpetuated by auto- or heterosuggestion after the return of the circulation on warming or on recovery with psychotherapy, does it become hysterical. If a nerve was damaged at the time the injury was inflicted, genuine organic anæsthesia may be present at first. This disappears with more or less rapidity, according to the severity of the injury; but, like the anæsthesia due to the coldness, it may be perpetuated by autosuggestion, and sometimes by heterosuggestion, if too frequent examinations are made by the medical attendant. We have shown that anæsthesia of this kind may eventually be purely hysterical, and curable instantaneously by psychotherapy, although its extent corresponds exactly with the cutaneous distribution of the injured nerve, and although it had led to burns or other injuries which had not been felt (*Fig.* 530).*

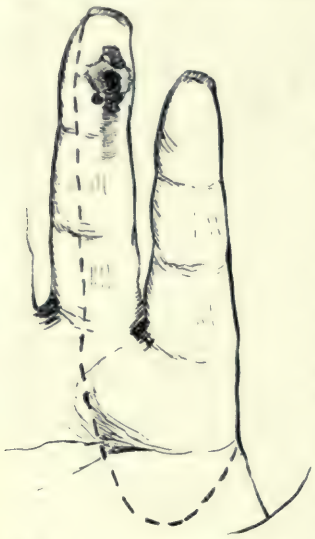


FIG. 530.—Hysterical anæsthesia in median nerve distribution, with unfelt accidental burn, cured by suggestion in less than one minute, ten months after injury to median nerve. (Capt. A. Robin.)

Hysterical anæsthesia of the median nerve, resulting in accidental burn, cured by suggestion in a minute after persisting five months.

Pte. F., age 36, received a penetrating wound of the right arm on Oct. 4, 1918, following which he had loss of muscular power of the hand, and anæsthesia of the area of skin supplied by the median nerve. The wound was excised at the casualty clearing station. He was admitted to Seale Hayne Hospital on Feb. 20, 1919, with an hysterical contracture of the fingers, the forefinger being rigidly extended, and the hand being blue and cold. He had median nerve anæsthesia, and on the outer side of the second finger was an ulcerated area about the size of a shilling (*Fig.* 530), which he stated was caused by his trying to hold a lighted match a few days previously. The contracture was

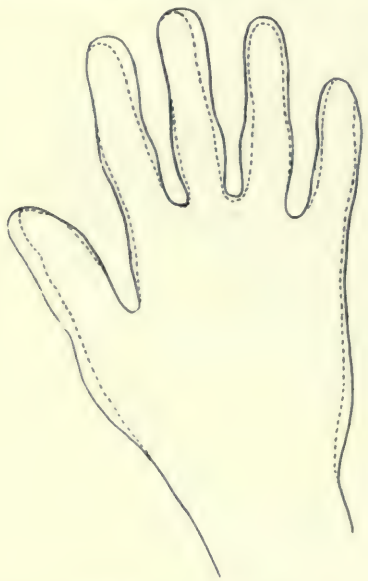


FIG. 531.—Tracing of hand (dotted) with hysterical contracture following wound of upper arm which had been present for sixteen months, superimposed on reversed tracing (continuous) of the other hand, showing atrophy of soft parts. (Capt. A. W. Gill.)



FIG. 532.—Atrophy of index finger of left hand, compared with normal finger of right hand, resulting from hysterical contracture of fingers of eighteen months' duration, drawn after recovery from the contracture.

* A. F. HURST and S. H. WILKINSON: Hysterical Anæsthesia, *Seale Hayne Neurological Studies*, I, No. 4, 1919.

cured by re-education and persuasion, and the next day the anæsthesia disappeared almost completely within a minute as a result of suggestion by means of faradism. With the restoration of the circulation and disappearance of anæsthesia the ulcer rapidly healed.

In addition to these changes, which also occur with temporary disuse, the long-continued deficient circulation in actual paralysis leads to malnutrition. Atrophy of the subcutaneous tissue occurs, with the result that the volume of the limb, particularly the tips of the fingers, greatly diminishes, and the increased blood-supply which occurs on warming the hand and on recovery from the paralysis only produces a comparatively slight increase in size, most of the loss of volume being due to actual atrophy. This is well shown in *Fig.* 531, which represents the tracing of a hand which had been hysterically paralyzed for many months, superimposed upon the reversed tracing of the corresponding normal hand; and *Fig.* 532, which represents the first finger of a paralyzed hand compared with that of the sound hand. The normal lines on the hands, especially the trans-



FIG. 533.—Skiagram of right and left hand, showing increased transparency of the bones of the right fourth and fifth fingers, and to a less extent the third finger, taken after recovery from a contracture involving the fourth and fifth fingers, with partial contracture of the middle finger, which had persisted for twenty months after wound of hand. The little and ring fingers also show atrophy of soft parts. (Major J. F. Venables.)

verse lines on the dorsal aspects of the joints of the fingers, become less marked and may even disappear. Owing to the diminished bulk of the fingers, the skin becomes too large for its contents and is thrown into longitudinal folds, especially over their palmar aspect. The muscles atrophy for the same reason, and also as a result of simple disuse, as their normal metabolism depends upon their activity. It is well-known that the corresponding anterior cornu cells of the spinal cord atrophy from disuse after a limb has been amputated. It is exceedingly probable that this would also occur in hysterical paralysis, as the disuse may be just as complete. If post-mortem evidence of this were forthcoming,

it would be an interesting confirmation of the far-reaching secondary organic changes which may follow disuse, even if this is purely functional as in hysteria.

The *x* rays show abnormal transparency of the bones, which is apparently due partly to deficient calcification and partly to absorption of the bony tissue, but we have never observed any definite alteration in their outline (*Fig.* 533). Although the joints occasionally appear to be enlarged, the *x* rays show no change in the articular surface: this corresponds with the fact, pointed out long ago by Paget, that hysterical disorders of joints never give rise to any anatomical change as the result of pressure exerted on abnormal surfaces, however long the condition may persist. The enlargement of the joint may be due partly to œdema from deficient circulation, but is more often simply apparent, and due to the atrophy of the soft parts round the shafts of the bones. Lastly, the nails become thin, brittle, abnormally opaque, and often show longitudinal grooves (*Fig.* 534).

Babinski and Froment rightly pointed out that the phenomena just described as accompanying functional paralyses and contractures caused by minor injuries to limbs, were not hysterical, because they were not due to suggestion, and were indeed incapable of being suggested, and because they could not be removed by direct psychotherapy. Unfortunately Babinski and Froment went further, and concluded that the paralyses and contractures which were associated with these non-hysterical phenomena were therefore also non-hysterical, but must be due to the same cause which gave rise to the latter. Although they are still uncertain as to their origin, they thought that the most likely explanation was that both the paralysis and contracture and the associated phenomena were reflex in origin, and corresponded with the atrophy and contracture in the neighbourhood of diseased joints, which Vulpian and Charcot long ago described as being due to reflex action.



FIG. 534.—Improved nutrition of nail, drawn six weeks after sudden recovery with psychotherapy from hysterical paralysis which had lasted for over a year. (Capt. A. W. Gill.)

We are, however, convinced that this explanation is incorrect, and that the paralysis and contracture are hysterical, and the associated phenomena are simply secondary to disuse. Cases of contracture in which all the signs described by Babinski and Froment were present have occurred in the absence of any wound, so that a reflex origin was excluded, their hysterical nature being subsequently proved by the cure which followed psychotherapy. Babinski and Froment had found considerable difficulty in curing paralyses and contractures of this nature by psychotherapy, which confirmed their opinion that they could not be hysterical. But our experience has been more fortunate, and we have not seen a single case in which psychotherapy failed to produce complete recovery. The accompanying table shows the results obtained in 100 consecutive cases treated at Seale Hayne Hospital, the majority, if not all, of which would have been diagnosed by Babinski and Froment as reflex nervous disorders. We have had cases precisely similar to every one of those of which photographs are reproduced in their book; the paralyses and contractures exactly fulfil the requirements necessary for a diagnosis of hysteria, being produced by suggestion and being curable by psychotherapy. The associated phenomena do not fulfil these requirements, and are therefore not hysterical; but they are none the less the direct result of the hysterical symptoms, for when the paralysis and contracture disappear with psychotherapy, they disappear with them. The return of movement is always accompanied by an improvement in the circulation, and the limb regains its normal colour and warmth. The electrical reactions and reflexes become normal at once, and the numbness and stiffness of the joints, however closely the latter may have simulated an organic condition, completely disappear. The only abnormal phenomena which are still present in the limb are the tendency to revert when at rest to the abnormal position, which I shall presently explain as a result of postural tone, and the

persistence of the trophic changes, which naturally require a considerable time to disappear completely. As soon as the limb is used as much as it was formerly—which should occur immediately the first treatment is concluded—and the circulation is consequently restored, the supply of nourishment becomes normal again, and at the same time the active contractions of the muscles stimulate their metabolism so that they, together with the soft parts, the bones, and the nails, gradually return to their original condition.

STATISTICS OF 100 CONSECUTIVE CASES OF HYSTERICAL CONTRACTURES AND PARALYSIS FOLLOWING MINOR WOUNDS AND INJURIES.

	RIGHT	LEFT	TOTAL
I. *Limb*—			
Arm ..	24	30	54
Leg ..	22	24	46

	ARM	LEG
II. *Nature of Injury*—		
Gunshot wound	23	26
„ „ with fracture	16	1
„ „ with amputation ..	4	—
„ „ and tetanus	1	1
Fractures (without gunshot wound) ..	3	2
Amputations (without gunshot wound) ..	1	1
Contusions	2	10
Dislocations	1	—
Sprains	—	2
Following operation	2	—
„ vaccination, burn, cellulitis ..	1	2
Trench feet	—	1
Total (100) ..	54	46

III. *Average Period of Treatment before Admission*, 11 months.
IV. *Duration of Treatment.*—*a.* Number cured at one sitting, 96. Average time required, 54 minutes. *b.* Duration of treatment in other cases, 4 weeks, 8 weeks (2), and 4 days.

Fig. 534 shows very strikingly the change in the nutrition of the nail which follows recovery. The drawing was made about six weeks after the patient had been cured by psychotherapy from hysterical paralysis which had lasted for over a year. The new nail which had grown since the cure of the paralysis was in every way normal ; the distal part of the nail, which is seen in the picture to be white, rough, and thin, in sharp contrast to the pink, smooth, and thicker proximal portion, is all that was left of the nail which was present before recovery took place. Three weeks later the last trace of the abnormal nail had been replaced by healthy nail.

The striking fact that the trophic changes are most obvious in winter, when the circulation is most feeble, and in individuals who have always had a poor circulation, is only what would be expected if our explanation of the secondary nature of these phenomena is correct ; it would be inexplicable if the reflex theory were accepted.

The excessive sweating which often occurs in these cases is less easy to explain. It may in part be a direct result of the cutaneous asphyxia when the circulation is unusually feeble. In cases of contracture in which the hand is tightly flexed, it is in part due to the air in contact with the palm being kept warmer than that in contact with the palm of the normal hand, and to the diminished evaporation which occurs in the enclosed space formed by the clenched hand. We have, however, observed in several cases, when recovery is incomplete and great efforts are being made by the patient to open and close

the hand, that the actual secretion of sweat continues to be very excessive. In such cases it is possible that the intense nerve impulses sent down from the brain to the centres in the spinal cord spread from the motor nerve-cells to the neighbouring sympathetic nerve-cells which control the secretion of sweat. This would explain the fact that the sweating may occur, though to a less extent, in the normal hand.

POSTURAL LENGTH AND POSTURAL TONE.

When hysterical paralysis, with or without contracture, has persisted for some months and psychotherapy leads to rapid recovery, it is often observed that, although the patient is able to perform every movement in a perfectly normal way at the end perhaps of an hour, he tends to maintain the abnormal posture, which was caused by the paralysis and contracture, directly his attention is withdrawn from the affected limb. A man, who as the result of a wound in the upper arm has developed hysterical monoplegia with contractures, resulting in the limb being carried with the elbow flexed and the fingers rigidly extended and crowded together in the form described as 'main d'accoucheur,' may recover every movement of his elbow, wrist, and fingers in a few minutes, and at the same time every trace of rigidity may disappear, but he will probably walk away from his treatment with his elbow flexed and his fingers still bunched together. Only if he constantly thinks of keeping his limb in the normal position, does the latter gradually become adopted even when no attention is given to it.

The abnormal postures produced by hysterical contractures persist after consciousness is lost when an anæsthetic is given ; this is in part due to the phenomenon observed by Babinski and Froment, that the contractures, which they regard as reflex in origin, are maintained until an advanced stage of anæsthesia is reached. But even after the muscular spasm upon which the contracture depends has completely disappeared, the abnormal posture remains, however deep the anæsthesia may be, so that it is clear that some other factor besides the muscular spasm must be present. Babinski and Froment, in common with Scott and most other observers, assumed that this was fibro-tendinous or fibro-muscular retraction ; but the complete return to normal with re-education without any physio-therapy proves that this view must be incorrect.

Another striking fact about these conditions is the maintenance of the abnormal posture of the arm or leg during sleep. On the few occasions on which I have been able to investigate the question, I have found that hysterical contractures disappear during sleep, but in spite of this the abnormal posture is maintained, so that it is only by actually manipulating the limb that the absence of the spasm of the affected muscles can be demonstrated. The experiments of Ballet, which he believed proved that hysterical contractures persist in sleep, really only proved that the abnormal posture persists. They consisted in fixing a paper band to the affected foot in such a way that any movement would tear it ; as it was not torn during the night, he concluded that the contracture had not relaxed. It is, however, much more probable that relaxation did occur, but the abnormal posture of the foot persisted, and no movement took place when the spasm disappeared.

After the hysterical contracture and paralysis have been cured, the abnormal posture is not only maintained during consciousness, but it also persists for a time during sleep and during anæsthesia.

From the above facts it is clear that some element is present which does not depend upon consciousness, but which has the effect of maintaining the abnormal posture during sleep and anæsthesia both before and after recovery from hysterical paralysis and contracture. It is obvious that this factor has nothing to do with hysteria, as it is independent of consciousness, and is neither produced by suggestion nor cured by psychotherapy.

I believe that the explanation can be found in what Sherrington has described as postural length and postural tone. Under normal conditions the position of a limb at rest is maintained as a result of the tone of its muscles, the exact position depending upon the relative tone of the extensors and flexors. The fingers, for example, are normally

slightly flexed, and remain so not only during the waking state, but also during sleep and during anæsthesia. Each individual muscle fibre has a certain degree of tone when at rest; and as for the greater part of every twenty-four hours it is at rest, its anatomical structure adapts itself to this tone; but it is capable of becoming shorter as a result of active contraction, and longer as a result of active relaxation.

If, for example, the line AB in *Diagram IV* represents the length of a muscle fibre in the condition of extreme relaxation, and AC its length in extreme contraction, its normal 'postural length,' which depends upon its 'postural tone,' will be AD. It is capable of shortening from AD to AC on active contraction, or lengthening from AD to AB on active relaxation. If as the result of continued contraction of the muscle—whether this is due

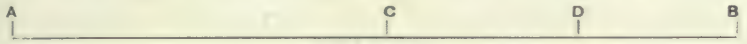


Diagram IV.

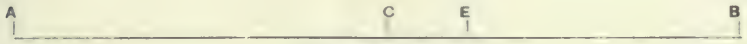


Diagram V.

to hysterical contracture, organic disease, or tetanus—its postural length, which is represented by AE in *Diagram V*, is kept constantly shorter than that due to the normal postural tone, the structure of the fibre will adapt itself to this length. Consequently, when recovery takes place, although the fibre is now capable of full contraction to the length AC and full relaxation to the length AB, yet it will tend to return when at rest, both during consciousness and during sleep and anæsthesia, to the abnormally short length AE. When as a result of an effort of will the limb is kept in a normal position for most of the day, the structure of the individual muscle fibres gradually returns to normal, and the normal postural tone is regained.

If this explanation is accepted, it is clear that in addition to the treatment of the actual paralysis and contracture in hysterical conditions, the patient must be taught to keep his limb in a natural position when he is not actually using it, and this can best be done by exercises in front of a looking-glass. Our observations show that the tone of a muscle adapts itself to new postures very rapidly, and in favourable cases a limb which has been in an abnormal position for a year or more returns to the natural one in the course of a few days.

The conception of postural length and postural tone of muscle has also considerable importance in the treatment of organic nerve injuries. A fundamental orthopædic principle is the prevention of the stretching of paralyzed muscles, the tendency until quite recently being to keep them in a condition of extreme relaxation. Experience has, however, shown that better results are obtained with a less degree of relaxation; in cases of dropped wrist due to musculospiral paralysis, for example, the hand was formerly kept in a position of extreme hyperextension; but recently it has been found that better results are obtained with a slighter degree of extension. The change in practice has resulted from experience, and not from theoretical considerations; but it is easy to understand why the most recent method of treatment is the best, as paralyzed muscles, whether the paralysis is organic or hysterical, are likely to recover their normal activity most rapidly if they are kept at their normal postural length, so that when a return to voluntary power takes place, the structure of the individual fibres corresponds with the normal postural tone. The ill effects of allowing the paralyzed muscle to be overstretched is probably not due, as has been generally supposed, to any injurious action upon its contractile power, but to the development of a new postural length which results in the muscle, when it recovers its contractive power, working under the greatest possible disadvantage. At the same time the abnormally short postural length of the opposing muscle is extremely disadvantageous.

Abnormal Postural Length and Postural Tone in the Absence of Organic Disease and Hysteria.—In our study of war neuroses, we have been constantly adding to the

conditions which we believe to be hysterical, but which were formerly supposed to be organic in nature or due to some other functional condition than hysteria. I believe, however, that the conception of postural length and postural tone should result in the exclusion from hysteria of a group of cases which have hitherto been regarded as hysterical. I have already spoken about the abnormal posture which persists after the cure of hysterical paralysis and contractures as a result of psychotherapy. It is not at all uncommon for organic disease and injuries to result in abnormal postures, owing to reflex action, the prolonged use of splints, the voluntary adoption of a posture with the object of relieving pain or, in rare cases, local tetanus. When the primary condition has disappeared, the wound having healed or the disease having cleared up, there may be no contracture or paralysis left of either organic or hysterical nature, all movements being perfect and the patient being well able by voluntary action to return to the normal position. But owing to the long maintenance of the abnormal posture, a new postural length of the muscles has developed, so that at rest the limb tends to remain in the same abnormal position as it was whilst the lesion was still active. There is nothing hysterical about this, as it depends upon a structural though temporary change, and it is not produced by suggestion, although it is curable by re-education, which, however, acts in a different way to the psychotherapy required for hysterical symptoms, as it simply teaches the patient to maintain by an effort of will the natural position for a sufficient length of time to enable a new postural length of the affected muscles to develop. It is thus clear that many cases of abnormal posture, as well as some cases of abnormal gaits, are really of this nature and not hysterical. The diagnosis from hysteria can be made by the complete absence of any paralysis or contracture, and from organic disease by the rapidity with which recovery occurs with re-education.

DIAGNOSIS.

The diagnosis of an hysterical contracture depends primarily upon the incompatibility of the symptoms with the injury. On careful examination it is generally at once clear that the exact form and extent of the contracture and paralysis cannot possibly be explained by the injury inflicted upon the affected muscles, or upon the nerves which convey motor impulses to them from the central nervous system. In some cases an injury to a nerve appears to be responsible for some of the paralysis present, but it is often found that the paralysis extends to muscles supplied by other nerves which could not have been injured. Moreover, an injury to a nerve cannot account for persistent spasm of the muscles it supplies, and still less for that of other muscles ; persistent muscular spasm resulting from injuries is thus invariably hysterical, unless the pyramidal tracts in the brain or spinal cord have been directly damaged. When a part of the condition is clearly hysterical, this should be cured, and an attempt made to cure the residual condition, however closely it may simulate the results of an organic lesion ; for the latter is often perpetuated as hysteria, and recovery of function may take place before the disappearance of the accompanying physical signs of organic disease, such as extreme muscular atrophy, loss of reaction to faradism, and abolition of the deep reflexes. I have already pointed out that vasomotor and trophic changes, which have in the past been regarded as conclusive evidence of organic disease, may be the result of disuse from hysterical paralysis, and that it is most important to recognize how impossible it is to distinguish by simple manipulation the stiffness of joints due to organic changes in the surrounding tissue from that due to local deficient circulation, quite apart from any associated muscular spasm, the degree of which should always be carefully investigated.

According to Babinski, a further criterion for the diagnosis of the hysterical nature of the paralysis and contracture leading to an abnormal posture is the possibility of voluntarily imitating the latter with complete accuracy ; for, having been produced by suggestion, and being independent of any organic condition, it should be capable of reproduction by voluntary effort. Experience has taught us that this criterion, though often a valuable aid in diagnosis, may lead one astray, as there are certain exceptions to the rule. If the posture is due to the perpetuation by suggestion of a position, which

developed under circumstances which uncontrollably placed the limb into a position the patient could not voluntarily assume, its maintenance for a more or less prolonged period before the responsible circumstances ceased to be operative would be sufficient to train the muscles involved to continue to act in the same way, and would also lead to the development of postural lengths of the muscles, which would help to keep the part in the abnormal position, even after psychotherapy had resulted in a cure of the contracture and paralysis. Thus, contractures developing after a splint or localized tetanus has kept the limb in an abnormal posture for a considerable period, and hysterical paralysis developing as the perpetuation of organic paralysis due to a nerve injury after regeneration has occurred, may be impossible to imitate. Lastly, it must be remembered that individuals vary considerably in the extent of movement they can produce at different joints. For example, a man developed a contracture of his hand with his fingers in extreme hyperextension (see *Fig.* 521), as a result of a wound of the forearm ; at first sight this was thought to indicate that the condition was organic, but it was then found that the patient was capable of producing voluntarily an equal degree of extension in his normal hand.

TREATMENT.

We have almost entirely given up hypnotism in the treatment of hysterical conditions, as our results were uncertain, and we have seen so many patients in whom prolonged treatment by hypnosis before admission had proved unavailing and had even given rise to new symptoms. Suggestion with the aid of electricity we rarely employ, except at the commencement of treatment in some cases of flaccid paralysis, in which the contractions produced in the paralyzed muscles powerfully appeal to the patient's mind.

Our method now begins with a full explanation of the cause of the symptoms in language suited to the patient's intelligence and degree of education, followed by persuasion and re-education, combined in most cases with manipulation, which doubtless acts to some extent by suggestion. A very important, but by no means essential, preliminary is the creation of a proper atmosphere of cure. Directly the patient is admitted, the sister encourages him to believe that he will be cured as soon as the doctor has time to see him, and she is often helped by the spontaneous efforts of other patients in the ward, who have been rapidly cured of similar symptoms and tell him of their cure. The medical officer sees him some hours later, and after examining him and coming to the conclusion that the condition is hysterical, he tells him as a matter of course that he will be cured the next day. By the following morning the patient is fully convinced that the hoped-for cure will take place ; as the medical officer is equally convinced that he will cure the patient, the two essentials for recovery are present. The nature of the actual treatment is really immaterial, but simple explanation, persuasion, and re-education have the great advantage of making the patient take an active part in his own cure, and remove any suspicion of charlatanism from the proceedings.

The patient is made to understand that any treatment he has already received has prepared the way, so that nothing now remains but a properly directed effort on his part, with our help, for complete recovery to take place. During the whole course of treatment he is engaged in conversation, and the meaning of each successive step is carefully explained. He is made to watch the contraction of the muscles and the play of the tendons of the normal limb, and to attempt to imitate them in the affected one.

In some cases it is not even necessary to touch the patient, mere explanation and persuasion being sufficient to cause him to relax any spasm which may be present, and then to perform the various movements of the part with quickly increasing strength and rapidity. In other cases the limb requires to be lightly supported at first, but here again no passive movements are employed. In cases of this kind the patient often expresses astonishment at the simplicity of the treatment, which succeeds in curing him in a few minutes in spite of the fact that he has previously been given massage and electricity for months without any obvious result. The explanation is that now for the first time he is made to take an active part in the treatment—to use his will power, instead of allowing

himself to become a passive agent in the hands of the masseuse. A few masseuses and electrotherapeutists realize the importance of active effort; but I have frequently seen a patient reading a newspaper which he holds with one hand, whilst his other hand is being massaged or treated with electricity exactly as if it did not belong to him. I have indeed very rarely seen a patient being encouraged throughout his massage or electrical treatment to take an active part in the proceedings. As a matter of fact neither electricity nor massage is of any use in these cases, although the average massage and electrotherapeutic department is crowded with them; for recovery should take place very rapidly, and then nothing but the ordinary activity of every-day life is required to restore any residual weakness due to the muscular atrophy caused by prolonged disuse.

In many cases of severe contracture more active manipulation is required. In our earlier cases we often forcibly moved the limb in the direction opposed to the normal action of the contracted muscles, however much the patient might complain of pain, the movements being repeated until complete relaxation and the power to perform voluntary movements were restored. Now, however, we realize that the production of pain often produces a more or less subconscious resistance to the treatment in the patient's mind. We have found that in almost every case it is possible by explanation and persuasion to get him to relax his muscles, so that passive movements can be carried out with the production of little or no pain, however powerful the spasm may be. When little or no resistance to passive movements persists, they are combined with and finally replaced by active movements until the condition of the limb is normal. In our experience it is never necessary, as recommended by Reeve, to continue the passive movements for several hours—relays of convalescent patients carrying on the treatment until finally the muscles became so fatigued and toneless that they are no longer capable of producing the original deformity. His experience is probably due to the fact that he believes his results are due to fatigue and not to suggestion; he therefore does not prepare the patient for rapid recovery, nor expect it himself, as he would do if he realized that recovery is really due to the suggestion of cure by the method he employs.

When very great difficulty is experienced in getting the contracted muscles to relax, the limb should be placed in very hot water, and the manipulations carried out when the circulation has been artificially improved in this way Some relaxation always occurs, because, as I have pointed out above, the rigidity is in part the direct result of the deficient blood-supply.

Passive movements are most effective if carried out by the medical officer himself, as the patient is engaged in conversation the whole time and made to take an active part in the movements from a very early stage in the first sitting. For this reason we never employ the mechanical appliances for performing passive movements, which have been boomed to such an extent during the last few years. Even when complete relaxation of spasm has been attained and the normal movements have been restored to a hand, the patient is very apt to forget this, and to continue to make the other hand do the work of both. After the condition has persisted for many months or even three or four years, it is only natural that this should be the case at first, if he does not think about it, as he has become so unaccustomed to having two useful hands. It is therefore of the greatest importance to give the patient some occupation, such as basket making or toy making, which will necessitate his using both hands from the very day on which recovery occurs. At Seale Hayne Hospital we have found that the men enjoyed working at a pottery we instituted better than anything else, and this has had the desired effect of rapidly training them to use the hand which is now no longer disabled. At the same time the patient is instructed to be careful to use both hands for all ordinary purposes, such as dressing and feeding himself, and in the case of the right hand he should at once begin again to write with it. A musician should be encouraged to play his instrument.

Finally, the patient should be taught to keep the limb in the proper position by an effort of will in order to restore the normal postural tone and postural length of the muscles. When the leg has been affected, it is necessary to give some re-education in walking for a few minutes in order to overcome any tendency to limp, due to the persistence of the

abnormal postural length of the muscles involved in the contracture and those which acted abnormally in order to compensate for the partial disability. Here again we have never found any apparatus, such as Zander's, necessary for the re-education of normal movements and restoration of full capacity, the ordinary activity of everyday life being quite sufficient, if the patient is made to understand that he must now use his limb exactly as if he had never been injured.

The following case is a single example out of a very large number, showing how rapidly complete recovery occurs even in very long-standing cases, in which all hope of cure had been given up.

Hysterical paralysis of the left deltoid of twenty months' duration, and hysterical contracture of the right biceps and triceps of nine months' duration, cured in a few minutes.

Pte. C., age 28, was wounded superficially over the left shoulder in August, 1916. He was in hospital for six weeks, and was then sent to his depôt. He was kept off duty, with the exception of walking exercises and attending lectures, on account of his inability to use his arm properly. He was then transferred to a Labour Company, and went to France in February, 1917. He received a slight wound of the right elbow in August, 1917. He was sent to England, and was in five different hospitals. He was transferred to Seale Hayne Hospital on May 14, 1918, with a diagnosis of "spasm of the right biceps." On examination, it was found that his right elbow was rigid and flexed at slightly more than a right angle. He was unable to abduct his left arm, the deltoid being quite flaccid. The latter condition had evidently been given up as hopeless, as no mention of the paralyzed left shoulder was made on his medical case-sheet. He had twice had his right arm forcibly straightened under an anæsthetic in other hospitals, but on each occasion the spasm had returned. With explanation, manipulation, and persuasion, the resistance of the muscles of the right arm was overcome in a few minutes. The left deltoid was stimulated with a faradic current in order to show the patient that the muscle could contract, and in ten minutes with vigorous persuasion he was able to move his left arm in any direction. He was immediately put on farm work and physical drill, and both arms soon became quite strong. He was discharged to duty on July 10, 1918. (Capt. S. H. Wilkinson.)

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REVIEWS AND NOTICES OF BOOKS.

Equilibrium and Vertigo. By Major Isaac H. Jones, M.A., M.D., U.S. Army. Pp. 444 + xv, with 130 illustrations. 1918. Philadelphia and London: J. B. Lippincott Co. 21s. net.

There is a wealth of information in this book which should be of interest and value to the general practitioner, to the specialist, and to the medical officer attached to the Air Service. In fact, the book has been adopted as a standard for the Medical Division of the Aviation Section of the Signal Corps of the United States Army.

The work is divided into two parts. *Part I* deals with the practical uses of a study of the internal ear. Appreciation is made of the work of Bárány and the Vienna school of otologists in developing the tests for determining vestibular stability. After perusal of *Chapter II* the general practitioner should face cases of vertigo with renewed confidence. At the end of this chapter the author points out that although 'ear examination' does not determine everything whatsoever that has to do with vertigo, it brings order out of chaos, and makes possible accurate diagnosis and intelligent treatment.

There is a special chapter on the ear and aviation, in which the author deals with the importance to the aviator of perfectly functionating internal ears; and he describes the tests for determining the balance mechanism as adopted in May, 1917, by the U.S. Army. We think he lays too much stress on the importance of the vestibular apparatus in flying. The fact is overlooked that, for his sense of balance in flight, the aviator is mostly dependent on his eyesight. Surgeon Graeme Anderson, R.N., by ascending blindfolded in an aeroplane, found that with vision cut off one has very little sense of balance or direction. Again, the author forgets that in clouds or in the dark the aviator depends greatly on his various instruments for his stability in flight.

In the chapter on 'The Ear and Seasickness' the various theories relating to the causation of *mal de mer* are discussed, and many facts of interest are related which should prove useful to the medical officers of the Royal Navy and mercantile marine. In the remainder of the first part of the book the values of the Bárány tests are discussed in relation to the neurologist, the surgeon, the ophthalmologist, and the otologist.

Part II is given up to the anatomical and physiological consideration of the internal ear. The Bárány tests for producing nystagmus, past pointing, and falling, are given clearly in detail, and illustrated in a novel way by means of cinematograph pictures. The latter part of the book is devoted to the analysis of pathological cases.

The illustrations throughout defy criticism, and the author is to be congratulated warmly on his work. We look forward to a second edition, and would like to see expressed in it his further views on the relation of the Bárány tests to the selection of candidates for aviation. It would be of immense value to have figures comparing the findings of these tests with each aviator's flying ability at the end of his period of instruction. Our experience has been that, the less easily stimulated the vestibular apparatus, the better the flying ability; but this is a debatable point. The trained acrobat's vestibular apparatus is not easily stimulated. Major Jones's book should be read by all medical men interested in aviation.

War Surgery from Firing Line to Base. By Basil Hughes, D.S.O., M.A., M.B., B.C. (Cantab.), B.Sc. (Lond.), F.R.C.S., Temporary Major R.A.M.C., T.F., and H. Stanley Banks, M.A., M.B., Ch.B. (Glasg.), D.P.H. (Cantab.), Capt. R.A.M.C., T.F. Large 8vo. Pp. 623 + x, with 9 coloured plates and 373 figures. 1918. London: Baillière, Tindall & Cox. 30s. net.

This is a book of quite exceptional merit. It is the outcome of three and a half years' experience gained on both the Eastern and Western fronts, during which period the authors have had the good fortune to serve in all the different areas between the firing line and the base hospital. Their service in the busy front areas was gained in France, so that they were able to apply all the newer methods of treatment that came into vogue there between 1916 and 1917 to their work at a large base hospital at Salonika. Thus they can justly claim a familiarity with war wounds in all their phases. They have had practical experience of the early days of the campaign when sepsis was rampant, and the surgeon, groping for knowledge and overwhelmed with work, was almost powerless. They have seen the gradual perfection of methods that began to evolve order out of chaos and turned failure into success, and they have taken part in the standardization of the most successful methods and their enforcement by order.

Having had experience of wounds in all parts of the line, they have had better opportunities than many writers upon war surgery of arriving at a true judgement as to what should be done in each area, and of viewing the treatment of war injuries as a whole in its true perspective. Those whose experience has been gained in a limited area only, are too prone to judge the subject as a whole by the small sample presented to them. Thus, the front-line officer is apt to be mostly concerned with questions of hygiene, mortality, transport, accommodation, and shock; the surgeon at the casualty clearing station with the early treatment of wounds; while the surgeons at the base hospitals concentrate upon the treatment of septic wounds, secondary operations, and the like. Each is apt to look upon his sphere of observation as the really important phase of war surgery, unless experience in other areas has enabled him to bring his observations into proper focus. The book before us is free from any fault of this character. It takes as its keynote the gunshot wound of the present war and the pathological processes that occur in it. This is the peculiarity of war surgery as we know it, and to this all other complications, such as injuries to bones or joints, are secondary in importance. And therefore it follows that it is the treatment of the wound itself that is the essential point.

The theme of the war wound is admirably dealt with by the authors. No clearer or more interesting survey of the subject has been written, and the reader's feeling on finishing it must be one of regret that the ephemeral nature of the subject must of necessity relegate so able a book ere long to the limbo of the many half-forgotten things connected with the Great War. The authors' apology in the preface for shortcomings on the score of the work being written under active service conditions in the East, where there was no access to any library of reference, is entirely unnecessary. An outstanding feature of the book is the great amount of information upon ancillary subjects that it contains. It is a remarkable tribute to the general knowledge of the writers that such a book could have been produced under such circumstances.

The chief part of the work upon which the book is founded is the personal experience of the authors. Most of this was done in the Salonika area, and it is interesting to find they are as enthusiastic in favour of the Carrel-Dakin method as the most devoted disciple in France. The history of this method will prove an interesting and illuminating study to students of war surgery. Apart from being a triumphant vindication of the value of associated departmental work—in the vernacular of the moment, 'team-work'—it has enjoyed in our armies the distinction of being almost the only surgical method laid down by order and enforced according to plan. There are some who think that the main lines of treatment in the army should be prescribed and enforced by authority, instead of allowing to each individual the unfettered exercise of his own judgement. The history of this method of treatment will afford these authorities much satisfaction, and in this connection the views of the authors upon the necessity of spending time—much time—in the acquisition not only of its general principles, but the minutest details of its technique, should be carefully taken to heart by those who are ready to introduce modifications of their own before they have mastered the teaching of its distinguished originators. All through the book the authors display a profound acquaintance not only with the true aim of the method, but also of its very varied applications. Nowhere, even in Carrel and Dehelly's own book, have we seen the matter better set forth.

The account of the general nature of wounds is excellent. All the special features of war wounds—the disruption and stunning of the tissues, and the latent and distant damage—are clearly emphasized and receive their due significance.

The information with regard to the bacteria of wounds is peculiarly rich. All the micro-organisms infecting wounds are clearly classified and described, and their biology is fully gone into. Their methods of growth, and the effects they produce upon the organism in general and the tissue in particular, are given with a clearness and precision that mark the writers as no mean pathologists. The description of the anaerobes is particularly good, and there is an excellent description appended of various simple anaerobic culture methods.

The subject of wound infection is ably dealt with, as might be expected from writers who have been so often called upon to treat wounds as they are made.

The predisposing causes of wound infection are fully examined. Fatigue, climate, and want of cleanliness have all played a part in this war in the production of trench ailments, the due importance of which has only recently been recognized. The authors present us with a description of the soldier's life that deserves to be read for its literary savour as well as its professional accuracy. Shock and hæmorrhage, dangerous enough as causes of immediate death, have assigned to them their proper importance as powerful predisposing causes of infection—one of the most valuable lessons that front-line treatment has taught us. As might be expected from surgeons who have served in the East, the authors have a good deal to say with regard to the evils produced by flies. We are interested to see that they have arrived at the conclusion, shared by many in different fields of warfare, that the larval form, the maggot, may have an apparently beneficial effect in some cases of badly lacerated wounds.

The chapter on the general pathological processes underlying the phenomena of wound infection is accurate; concise; but ample for the student or the practising surgeon. The microscopic appearances of the wound secretions at various stages of treatment, based of course upon the routine at Compiègne, are all that could be desired both in the way of illustration and description. All this leads up to the description of the treatment of wounds by the Carrel-Dakin method, which for the authors is the only method deserving of any serious consideration. Upon this subject

they are perhaps better qualified to speak than many, for, owing to the military situation, they were able to treat a very large number of cases from beginning to end. This special experience therefore enables them to express opinions upon the merits of the Carrel-Dakin treatment that must be received with due respect. It is one thing to give an opinion upon a method of treatment after such an experience of it in a long series of cases, and quite another when views are founded upon experience derived from cases that have passed through many hands. The results claimed by the writers go a long way to counterbalance the obvious objections that the complicated nature of the treatment is apt to provoke in the minds of those who have not practised it assiduously and with devotion. Its exact place in surgery is still difficult to define, but there can be no doubt that under certain circumstances it is invaluable, and cannot be efficiently replaced by any other plan.

The second half of the book is devoted to the treatment of special injuries. The chapter on injuries of joints is of a high degree of merit. It is full of important anatomical and pathological information, while the part devoted to treatment is of exceptional interest. The question of immediate resection of the wound track in these injuries, and especially those of the knee, is dealt with ably, but the chief interest lies in the results obtained by the use of the Carrel-Dakin method. As the writers followed their cases from beginning to end, their report upon this difficult group of injuries ranks in value with the best accounts we have seen in the literature of the subject.

We have said enough to indicate that this book should be in the hands of all who are concerned with war surgery. It cannot fail to interest, even when the methods followed by the authors do not coincide with those of the reader. It is pleasantly written and admirably got up. The illustrations are good, though the coloured plates might have been dispensed with.

Surgery in War. By Lieut.-Colonel ALFRED J. HULL, R.A.M.C., F.R.C.S. Second edition. Pp. 624 + xv, with 210 illustrations. 1918. London: J. & A. Churchill. 25s. net.

THIS book may justly be regarded as the standard text-book on the surgery of this war. The first edition, issued early in the campaign, was for a long time the only book of its kind in the language that could be regarded as comprehensive. Because of its general accuracy and completeness it became the guide and book of reference for all who had to deal with war casualties. The increase of knowledge and the ever-widening scope of surgery in war has called for a revision of the original work, and, as might have been expected, the magnitude of this task has compelled the author to call to his assistance a number of collaborators. To each of these a subject to which he has devoted special attention is allotted. The result is a large text-book, which, while it may suffer somewhat from the point of view of homogeneity, undoubtedly gains considerably in completeness and in authority.

The book, after a preface by the Director-General, Sir T. Goodwin, opens with an excellent introduction by Colonel Pilcher, C.B., D.S.O., which calls attention to the recent changes that have been made in the treatment of the wounded, the developments in the methods of collection and forwarding of the injured men, and the improvements in surgical technique. It is interesting and instructive to find this authority writing: "It would almost seem that the chiefs of the Army Medical Service, acting by the advice of their surgical consultants, must in the future exercise a more direct control over the various methods of treatment of wounds in warfare. This might well be done without interference with individual enterprise and the issue of direct orders, or even destructive criticism of existing methods, but by education in methods scientifically chosen and described in pamphlets officially approved and issued at intervals." This is a view that many who have had experience of the conditions prevalent in the earlier stages of the war will cordially support. Lieutenant-Colonel Hull has some excellent remarks upon the same subject, in connection with the choice of method of wound treatment, which are to be commended strongly to the notice of all concerned His description of the methods of treatment of wounds is very complete and full of technical detail, and his views as to their relative value are sound and practical. There are few surgeons of experience who will fail to agree with him when he says: "Provided the surgical treatment is correctly carried out at the proper time, it is immaterial what particular treatment is adopted."

One of the best chapters in the book is that on tetanus by Dr. C. H. Browning, a good deal of which has already appeared in the columns of this journal. It is very concise, but it is admirably clear, and contains practically all that is of value in our knowledge of this baffling disease at the present time. The subject of anaerobic infection is adequately dealt with by Captain A. A. Petrie, and that of the treatment of gunshot wounds of the head is brought well up to date by the incorporation of the excellent work of Harvey Cushing. It would have added value to this section had the author been more critical as to the relative merits of the methods he describes. The section on the injuries of blood-vessels is very meagre, except in regard to the methods of transfusion of blood, which has been brought well up to date. A somewhat similar objection may be made to the chapter dealing with gunshot wounds of joints. This contains a great deal of valuable information as to methods, but there appears to be some want of critical appreciation of their value. It is true that the subject is really the most difficult one in the entire range of war surgery, but it is just on this account that the beginner asks for firm guidance from his more experienced colleague.

The best chapter in the book is undoubtedly that on wounds of the abdomen by Colonel Owen Richards, C.M.G., D.S.O., who was one of the small band of pioneer workers in this much revolutionized branch of war surgery. It is full of information, all of it clear, concise, and authoritative. It is worth while to quote his concluding paragraph on the future of abdominal surgery in war. He says: "Abdominal surgery, on the other hand, has only been called on to apply a technique already developed and generally accepted to the treatment of a new group of injuries under unusual conditions. The only question ever in dispute was whether it could and should be so applied or not, and, now that this has been decided, the only changes we may expect will be determined by the varying possibilities of bringing the wounded man and the surgeon together early and under good conditions." All who remember the views held by those in authority in the early days, and the difficulty that the advocates of operation had to obtain permission to decide by actual practical experience whether their views were right or not, may well rejoice that there were stout fighters for the belief that injuries of the abdominal contents in warfare did not call for a line of treatment totally incompatible with that suited to similar injuries in civil life.

Gunshot wounds of the chest are excellently dealt with by Captain W. Miller, who has brought the subject thoroughly up to date. The same may be said for that on shock. The author's account of the treatment of fractures is a little disappointing. It is very full of detail, but it leaves the reader in some confusion as to the best methods to follow. There are really very few methods or appliances in the treatment of fractures that are of outstanding merit, and the author's long war experience should have enabled him to discriminate accurately. He certainly does not do adequate justice to the valuable work of his distinguished colleague, Major M. Sinclair, C.M.G., to whose untiring efforts the present improved condition of the treatment of fractures is so largely due.

It may fairly be said of the book that it maintains its position as the leading text-book upon the subject in our language, and that it is an indispensable work for all who are called upon to practise the surgery of war. It is admirably got up and copiously illustrated. It is a great source of satisfaction to know that so useful, comprehensive, and widely appreciated a book has emanated from a member of the Regular Army Medical Service, who from the first day of the war has been engaged on active service overseas.

The Operative Treatment of Chronic Intestinal Stasis: By Sir Arbuthnot Lane, C.B. Fourth edition. Large 8vo. Pp. 328 + xii, fully illustrated. 1918. London: Henry Frowde and Hodder & Stoughton. 20s. net.

The fourth edition of Sir Arbuthnot Lane's work has been revised, and several new chapters, written by a number of contributors, have been added. Though there is no doubt that many facts of real importance have emerged from the author's prolonged investigations on the subject, it must be admitted that he has failed to substantiate his claim that the vast majority of all the diseases which flesh is heir to are caused by intestinal auto-intoxication.

The book opens with descriptions of five skiagrams of the fractured lower epiphysis of a humerus, of illustrations of the spines of a brewer's drayman and a coal-heaver, and of the skeletons of a coal-trimmer and a shoemaker. So much importance is attached to the last two, that a second description of the same skeletons, occupying 78 pages and illustrated by the same 16 illustrations, appears in the middle of the book. The ingenious application of these anatomical studies to the pathogenesis of intestinal adhesions loses most of its interest from the fact, proved by Professor Keith in a later chapter, that adhesions have little, if any, connection with intestinal stasis.

Appetite for food and sexual appetite are discussed together, both by the author and by Mr. Chapple, as if they were analogous physiological phenomena, a most extraordinary notion; and these 'appetites' are said to be seriously affected in intestinal stasis unless the patient is fortunate enough to have red or towy-coloured hair. The favourable effect of marriage on women with intestinal stasis is ascribed to the prostatic secretion, which counteracts the auto-intoxication, an opinion which surely requires more evidence in its support than the surprising statement that an extract from the prostate of the ram "has been administered very generally and apparently with marked benefit"—but whether by mouth or by a vaginal douche the author does not tell us.

The list of diseases which the author attributes to intestinal stasis begins with flat-foot and knock-knee, passes on through almost every pathological change in every organ of the body—such as atrophy, adenoma, cysts, and cancer of the thyroid in addition to exophthalmic goitre, as well as *all* tuberculosis, which can always be cured by colectomy (except advanced phthisis)—and concludes with cancer, which he describes as "the last chapter in the three-volume story of chronic intestinal stasis"! Whatever element of truth there may be in his work, statements of this kind are so obviously and grossly exaggerated that one cannot help doubting every other conclusion which the author reaches.

He describes the medical treatment of intestinal stasis as "tedious, dangerous, and at the best palliative." But the operative treatment must surely have infinitively greater danger, or it would be inconceivable that he should seriously state that "it would seem almost justifiable in an unmarried girl to resort to a pregnancy rather than to operative interference."

No more damning evidence against the author's conclusions with regard to the causation and effects of intestinal adhesions could be offered than the chapter contributed by Professor

Arthur Keith, "On the Large Bowel; from an Anatomist's Point of View." He shows that Lane's band, Jackson's membrane, and all the other bands which have been described, are present in at least thirty per cent of new-born children. The slighter forms described by Lane cannot be regarded as abnormal, but in pathological conditions the adhesions may be considerably exaggerated. In spite of his unique opportunities, Keith has not obtained a single specimen removed at operation which showed the usual signs of chronic obstruction, namely, marked constriction at the site of the adhesion or hypertrophy of the muscular coat above the adhesion. He concludes that "bands and adhesions are not the cause, but a mere accompaniment of the stasis, of embryological or pathological origin." He believes that the intestinal stasis is not due to mechanical obstruction, but to a disturbance in the neuro-muscular mechanism of the bowel, a view which he has described in detail in this journal (1915, vol. ii, p. 567).

Dr. Jordan contributes two chapters, illustrated by admirable skiagrams, his interpretation of which, however, shows the danger of attacking a problem from a single point of view; few of his conclusions are justified by the evidence he brings forward, and, as is well known, they are not supported by the large majority of radiologists. In common with the other contributors to the volume, there is a curious absence of acknowledgment of the work of others. In his reference to ileocæcal insufficiency, for example, although this is clearly inspired by the work of Case, no mention is made of this author. Many conflicting statements are made; thus, it is curious to read on page 303 that ileocæcal incompetence is 'nearly always' present in intestinal stasis, whereas on page 314 the terminal ileum is said to be 'quite constantly' dilated owing to the obstruction caused by spasm at this same point. According to Jordan a narrow intestinal lumen is sufficient evidence for the diagnosis of colitis, although it is obvious that the *x* rays can prove nothing more than that the colon is contracted, which may be due to spasm or simply to its being empty. It does not indicate the presence of inflammation, and indeed in colitis the colon is dilated more often than it is contracted, except in the mucomembranous variety.

In an interesting chapter Professor Adami repeats his belief that Lane is wrong in attributing the symptoms of intestinal stasis to auto-intoxication, his own researches and those of Rosenow having led him to believe that 'subinfection' or the continuous passage of bacteria from the bowel to the blood-stream is the main factor, though he now admits that in some cases toxæmia may play a part by lowering the resistance of the tissues to subinfection.

Dr. Leonard Williams has written a chapter on the "Medical Aspects of Intestinal Stasis," which might have been more appropriately entitled, "Humorous Aspects." It cannot be regarded as a serious contribution to the subject, but it is remarkable that, though it forms a part of a work on "The Operative Treatment of Intestinal Stasis," he appears to regard medical treatment as always sufficient, as no mention is made of surgery.

Dr. Nathan Mutch has written two chapters, the first a very technical one describing his researches on the bacterio-chemistry of the small intestine, and the second on chronic streptococcal infection of the bowel. One would have welcomed full clinical histories, continued after the discharge of the patients from hospital, before accepting the theory he shares with Lane that chronic nephritis, ulcerative colitis, chronic infective endocarditis, and diabetes are the results of chronic intestinal stasis. Considering how easy it is to aspirate the duodenal contents by means of Einhorn's evacuator, more evidence should have been forthcoming of the supposed relationship between diabetes and duodenal stasis and infection, which are regarded by him as secondary to intestinal stasis. As it is, the *x*-ray and bacteriological evidence he offers is worthless, particularly in view of the observations of Case, who found duodenal stasis in one and duodenal dilatation in none of a series of 72 cases of diabetes, examined with the *x* rays. In the single case of chronic nephritis described by Mutch there is no evidence of any causal connection between it and the intestinal condition, and the results of treatment are not even mentioned.

After the author's remark in his introductory chapters, that "if women were not imperfectly drained the gynæcologist would not have been evolved," one is led to expect something more convincing than Mr. Chapple's chapter on the gynæcological aspects of intestinal stasis. It contains nothing but bald statements, which are unsupported by any real evidence, and few of which would be accepted by any gynæcologists of experience.

Mr. Chapple states that there is now a series of several hundred cases, which have undergone operations for intestinal stasis, which are available for investigation. In view of this, it is unfortunate that neither Sir Arbuthnot Lane himself nor any of the contributors to his book have taken the trouble to compile an accurate record of the end-results of the whole series, which would be much more convincing than the mere statement "that the results are extraordinarily good."

The only detailed report of a consecutive series of cases appears to be that published by Lane in 1908; of 37 cases operated upon for chronic intestinal stasis, 7 died as the immediate result of the operation, 1 died six months later of intestinal obstruction, and 1 a year later from exhaustion. In many cases the ultimate result was not yet known, as 12 had only been operated on between a month and a year before the date of publication. W. S. Bainbridge (*Brit. Med. Jour.*, 1913, ii, 1129) reported that out of 50 female hospital patients upon whom Lane had performed colectomy for stasis between May, 1909, and October, 1913, 2 died from sepsis, 1 from pulmonary embolism, and 5 returned suffering from adhesions, of whom 1 died from peritonitis after a second operation. Colectomy is recommended for duodenal ulcer rather than gastro-enterostomy; any benefit which may follow the latter is ascribed to division of the circular muscle fibre, which diminishes the activity of peristalsis, and not to the making of a stoma.

The opinions offered by Sir Arbuthnot Lane in support of his views lack adequate corroboration from his own work, or from that of any of the contributors to this volume. Where we look for reasoned argument, we find wild assertion; we seek in vain for any record of mortality, or for any series of cases in which the previous history, the operative disclosures, the risk of operation, and the late conditions are set forth in a manner which allows a reader to form his own judgement. Our faith is tried to breaking point.

Transactions of the Sixth International Dental Congress. Edited by H. R. T. Brooks. Published by the Committee of Organization, 19, Hanover Square, W.

The publication of the Transactions of the Congress held in 1914, coincidently with the outbreak of war, has necessarily been delayed.

The proceedings were curtailed, papers promised and doubtless prepared were not presented. Under the circumstances it is surprising that this volume should contain so many interesting and valuable papers and reports. The latter vary much in character; they attempt an epitome of knowledge in certain subjects, but in many cases refer only to the work done in that country in which the writer resides. Thus, for instance, the report of T. Sydney Smith on pyorrhœa alveolaris, good as it is, contains among the fifty-two references not a single one to any paper published outside of the United States. This is equally true, perhaps more so, of some reports presented by English writers. Had these papers been discussed—or, probably more correctly, had the discussion been reported—this local character would have disappeared. The absence of reporters at the meeting of the sections of most Congresses is a fact to be deplored, for it has proved to be an inefficient method to rely on a speaker handing in a précis of his remarks.

The absence of a discussion is often a matter for great regret; thus, in view of the part saliva plays or may play in the causation or prevention of dental caries, it would have been of value had the report by E. E. Kirk on the chemistry and physiology of the saliva been amplified by some account of the work done in other countries than the United States. Several writers do give an international report, and their papers gain thereby. Among these are Brooke Nicholls, on the teeth of Australian and Tasmanian aboriginals; Angalo Chiavaro, on supernumerary cusps upon temporary molars; H. P. Pickerill, on the etiology of dental caries; George Villain, *sur l'unification de la terminologie et des classifications des déviations dento-maxillo-faciales*. Amongst the papers describing original work, we note with pleasure that of A. W. Wellings, on staining dental and adjacent tissues of certain rodents by means of trypan blue introduced into the animal during life, which is excellently illustrated by Lumière autochrome plates; and that of James W. McBain and W. A. Knight, on the chemical constitution and the physico-chemical properties of dental amalgams, which contains the results of much work done in this subject by themselves and others in the Bristol University, and considerably modifies opinions previously accepted.

Two papers, one by Truman W. Brophy, the other by H. Blakeway, on the operative treatment of cleft palate are of interest. The former believes that defective phonation has been due in many cases to lateral incisions in the soft palate, which in his opinion should never be done.

We may congratulate the editor on the way he has done his work, and the publishers on the way the volume is produced.

Nerves of the Human Body, with Diagrams. By C. R. Whitaker, F.R.C.S. Second edition, revised and enlarged. Edinburgh: E. & S. Livingstone. 3s. 6d. net.

As the title indicates, this small work is only concerned with the anatomy of the nerves, and not with its surgical application. This war and its small missiles have made many surgeons revive their knowledge of the anatomy of the nerves of the human body, and this probably has stimulated the demand for a small book thereon, well written, and by an authority on the subject. Naturally, the smallness of the price of the book has forbidden its more elaborate illustration. The figures are well done, as would be expected in a book in its second edition. Almost the only criticism called for is in regard to the index. This is but a small point, and hardly detracts from the value of the work; but only one saphenous nerve appears indexed.

END OF VOLUME VI.

INDEX TO VOLUME VI.

PAGE

A'COURT, MAJOR HOLMES, and CONNELLY, Capt. A. Waldo: Congenital abnormality of the wrist - - - - - 148
'Active movement' splint for suppurative arthritis of the knee - - - 570, 571
ADAMS, Capt. Joseph E.: Restoration of the urethra by means of Baer's membrane 494
Affections of the large joints due to gunshot wounds, their late results and treatment 190
Alternative methods in peripheral nerve injury where suture, etc., is inapplicable 291, 453
Alveolus, fractures of - - - - - 86, 87
Amputations, primary and delayed primary suture in - - - - - - - 107
Anæsthesia due to deficient circulation in hysterical contractures - - - - - 596
Anæsthetic, general, in cases of fractured femur at the base - - - - - - - 353
Aneurysm and brachial plexus injury associated with peripheral nerve lesions - - 450
Ankle-joint, gunshot wounds of, primary suture 107
— — — late treatment of - - - - - 201
— splints - - - - - - - - - 202
Ankylosis after gunshot wounds of joints 195, 251, 252, 254, 255, 271
— of elbow, best position for - - - - 254
— — treated by arthroplasty, compared with results of excision - - - - 271
— shoulder, best position for - - - - 255
— wrist, treatment of - - - - 251, 252
Anterior crural nerve, injury of - - - 434
Antiseptics in the treatment of gunshot wounds by primary suture - - - 93, 103
Apparatus for active mobilization in suppurative arthritis of the knee - - - - - 571
— Crile's, for holding the fragments in difficult cases of fracture of the femur - - 458
Appendix, a case of torsion of the - - 327
Army Medical Collection, how it was formed - 537
— — — macerated bones in, showing the effects of gunshot injuries (*see also* Cranium) - - - - - - 537
Artery, axillary, a case of contusion of - - 15
Arthritis, suppurative, of the knee-joint, new method of treatment (*see also* Knee-joint) - - - - - - - - - 566
Arthroplasty for ankylosis of elbow, compared with excision - - - - - - 271
Aseptic technique in the operative treatment of ununited fractures - - - - - 220
Axillary artery, a case of contusion of - - 15

BACTERIOLOGY of gunshot wounds 93, 96, 97, 109, 111, 124
— — — collection of material - - 93, 111
— — — cultural methods - - - - 111
Baer's membrane, restoration of urethra by means of - - - - - - - 494
Bandolier shoulder-abduction splint - - 196
Base hospital, treatment of cases of fractured femur at (*see* Femur)
Baths, whirlpool, in peripheral nerve lesions - 283
Bilateral ovarian dermoid cysts simulating renal colic - - - - - - - - 468
Biographical Notes:—
Sir Benjamin Collins Brodie, Bart. - - 157
Henry Cline - - - - - - - 12
Sir William Fergusson - - - - - 479
Robert Liston - - - - - - - 333

PAGE

B.I.P.P. in primary and delayed primary suture of gunshot wounds - 95, 97, 98, 103
Bladder, anatomy of - - - - - - 24
— injury in warfare; a study of 53 cases - 24
— — — associated injuries - - - - 30
— — — complications - - - - 37, 45
— — — cystoscopy in - - - - - 34–37
— — — importance of perivesical tissues - 42
— — — late results - - - - - - 45
— — — methods of examination - - - 33
— — — missile and its track - - 26 *et seq.*
— — — mortality and causes of death - 39
— — — particulars of cases - - - - 47
— — — signs and symptoms - - - 31
— — — treatment - - - - - - 40
— — — — of associated injury to other pelvic organs - - - - 44
— — — — extraperitoneal wounds - - 41
— — — — intraperitoneal wounds - - 40
— — — — wound in parietes - - - 43
Blake's apparatus for extension treatment of fractures - - - - - - 168–71
Blood toxicity in shock - - - - - - 403
— transfusion in shock - - - - - 407
— vessels in shock - - - - - - 404
— volume in shock - - - - - - 404
Bolts, fixation of bone grafts by - - - 237
Bone changes due to deficient circulation in hysterical contractures - - - - - 598
— fragments, removal in cases of fractured femur at the base - - - - - 355
Bone-grafting in non-union of forearm bones - 252
— for ununited fractures - - - - - 230
— — — fixation by accurate joinery - - 234
— — — — by intramedullary pegs - - 234
— — — — nails, split pins, wires, screws, bolts, and plates - - - 237
— — — — suture - - - - - - 233
— — — of the mandible - - - - 65
— — — mechanical fixation of graft - - 233
— — — results obtained in 34 cases - - 238
— — — rôle of the periosteum - - - 231
— — — source of graft - - - - 233
— — — vital conditions necessary - - 231
— growth and bone repair: researches by Ollier of Lyons and Macewen of Glasgow 160
— — — — — by Syme and Goodsir - - 19
Bones, Izzard's method of macerating - - 538
— macerated, showing the effects of gunshot injuries, in the Army Medical Collection (*see also* Cranium) - - - - - 527
Bony block after gunshot wounds of joints - 195
Brachial plexus, injury of - - 308–10, 451–3
— — — and aneurysm associated with peripheral nerve lesions - - - 450
Bradshaw lecture, 1918: On cancer of the tongue (D'Arcy Power) - - - 336
Brain, foreign bodies in, a new method of localization and extraction of - - 409
BRODIE, Sir Benjamin Collins, Bart., biographical notes of - - - - - 157
Bullet tracks in gunshot wounds, sterility of - 111
BURROWS, Capt. Harold: A case of congenital defect of the thorax, with Sprengel's deformity - - - - - - - 325
— — — and KAZANJIAN, Major V. H.: Treatment of gunshot wounds of the face accompanied by extensive destruction of the lower lip and mandible - 74
Bursts of the intestine - - 135, 140

PAGE

CALCULI as a complication of war injuries of the bladder - - - - - 45
Calico, unbleached, for slinging limb in Thomas splint - - - - - - - - 360
Caliper splint, walking, for cases of fractured femur - - - - - - - - - 375
Calipers, engineer's, for extension of fractured femur - - - - - - - - 357, 358
Callus production without bone suture in the treatment of ununited fractures - - 215
Calvaria (*see* Cranium)
Cancer of the tongue (Bradshaw lecture, 1918) (*see also* Tongue) - - - - - - 336
'Capsulectomy' in peripheral nerve injury - 442
Caries of teeth as a possible cause of the increase in cancer of the tongue - - - - 345
Causalgia in peripheral nerve injury - - - 447
Chain, eversion, for drop-foot - - - - - 517
Circulation, deficient, in hysterical contractures, secondary changes due to - - - - 593
CLINE, HENRY, biographical notes of - - 12
COLE, PERCIVAL P.: Ununited fractures of the mandible; their incidence, causation, and treatment - - - - - - 57
Colic, renal, simulated by bilateral ovarian dermoid cysts - - - - - - - 468
Colostomy and colectomy, a procedure for avoiding - - - - - - - - 382
Congenital abnormality of the wrist - - 148
— defect of the thorax, with Sprengel's deformity - - - - - - - - 325
— elevation of scapula (Sprengel's shoulder), a case of - - - - - - - - 146
Congestion, passive, in the treatment of ununited fractures - - - - - - 214
CONNELLY, CAPT. A. WALDO, and A'COURT, MAJOR HOLMES: Congenital abnormality of the wrist - - - - - - 148
Contractures, ischæmic, and their treatment 250, 251
— war—localized tetanus, reflex disorder, or hysteria (*see also* Hysterical Contractures) - - - - - - - - - 579
Contused injuries of the cranium (*see* Cranium) 539
Contusion of the axillary artery, a case of - 15
CORNER, MAJOR EDRED M.: The structure, forms, and conditions of the ends of divided nerves, with a note on regeneration neuromata - - - - - - 273
Counter-extension in the treatment of war fractures - - - - - - - - 167
Counterpoise system for cases of suppurative arthritis of the knee - - 571, 572, 573
Cranium, atypical injuries of - - - - - 554
— contused injuries of - - - - - - 539
— — — injuring external but not internal table - - - - - - - - 541
— — — in which external table shows slight injury and inner table marked comminution - - - - - 541
— — — grooved and massive variety - - 543
— — — without depression of external table but with fracture of internal table 540
— gunshot injuries of - - - - - - 539
— penetrating injuries of - - - - - 546
— — simple - - - - - - - 546
— — — with secondary injury to another portion of the cranium - - - 547
— perforating injuries of - - - - - 548
— showing disruptive effects of close-range high velocity missiles - - 556, 557
— — result of severe crushing accident - - 554
— specimens showing various reparative processes - - - - - - - 551
— — in the War Office Collection in which a trephining or decompression operation had been performed - - - - 550

PAGE

CRILE, CAPT. DENNIS W.: Fracture of the femur: a method of holding the fragments in difficult cases - - - - - 458
Crucial ligaments, anatomy of - - - - - 176
— — clinical manifestations of injuries to - 178
— — diagnosis and treatment of injuries to - 176
— — mechanism of - - - - - - 177
Cultural methods in the bacteriology of gunshot wounds - - - - - - - - 111
Culture tests in primary suture of gunshot wounds - - - - - 93, 111, 124
Cultures from gunshot wounds, Stokes' swab and tube for taking specimens - - 93
Cystitis as a complication of war injuries of bladder - - - - - - - 38, 46
Cystoscopy in war injuries of bladder - 34–37
Cysts, bilateral ovarian dermoid, simulating renal colic - - - - - - - - 468

DAVIES, CAPT. TREVOR B.: An unusual type of fracture dislocation of the upper end of the humerus - - - - - - 466
DAW, S. W.: Affections of the large joints due to gunshot wounds; their late results and treatment - - - - - - - 190
Decompression operations, crania in the War Office Collection showing - - - 550
Delayed primary suture of gunshot wounds 98, 103, 109
Dermoid cysts, bilateral ovarian, simulating renal colic - - - - - - - - 468
Diagnosis and treatment of injuries to crucial ligaments - - - - - - - 176
Digestion of the œsophagus as a cause of post-operative hæmatemesis - - - 523
Dilatation of the stomach, acute (*see also* Stomach) - - - - - - - - 125
Disabilities resulting from hysterical war contractures - - - - - - - 579
— of the upper extremity in military surgery, treatment of - - - - - - 248
Disability of the limbs, functional, treatment in a special military surgical hospital - 497
Dislocation and fracture of upper end of humerus, unusual type of - - - - - - 466
— subastragaloid, reduced by operation after 7 weeks - - - - - - - - 144
Displacement of the mandibular meniscus and its treatment (*see also* Mandibular Meniscus) - - - - - - - 385
Diverticulum, Meckel's, gunshot injury of - 324
DOBSON, LIEUT.-COL. J. F., and HIGGINS, CAPT. W. R.: A case of contusion of the axillary artery - - - - - - - 15
DOOLIN, WILLIAM: Acute dilatation of the stomach - - - - - - - - 125
Drainage in primary suture of gunshot wounds 96
Dressings in primary suture of gunshot wounds 97
Drop-foot, eversion chain for - - - - - 517
— shoe splint for - - - - - - - - 202
DRUMMOND, MAJOR HAMILTON: Rupture of the small intestine into the mesentery, the result of indirect violence of a missile 140
DUNN, MAJOR NAUGHTON: The treatment of disabilities of the upper extremity in military surgery - - - - - - - 248
Dyes, use of, in distinguishing living from dead tissue in excision of gunshot wounds - 94

EBURNATION as a cause of non-union of fractures - - - - - - - - 210
Elbow, best position for ankylosis - - - 254
— bone blocking flexion of - - - - - 255
— flail - - - - - - 198, 253, 269, 270
— — jointed poroplastic splint for - - 198

PAGE

Elbow and humerus, fractures of, treatment in relation to the primary suture of wounds - - - - - 99, 107
— late treatment in gunshot wounds of- - 197
— myositis ossificans affecting - - - 255
— primary excision for wounds of, method of limited excision - - - - - - 268
— — — — preservation of muscular attachments - - - - - 269
— — — — relation between amount of bone removed and subsequent functional result - - - - - 265
— — — — — of the extensive operation to sepsis - - - - - 268
— — — — results of - - - - - 265
— — — — — compared with those of arthroplasty for ankylosis - - - 271
— — — — table of particulars of 11 cases - 266
— treatment of disabilities resulting from war wounds - - - - - - 253
Electrical changes in peripheral nerve lesions 282, 287, 318
— treatment in peripheral nerve lesions - - 284
Epididymitis as a complication of war injuries of the bladder - - - - - 38, 46
Ether, results of employment as antiseptic in primary suture of gunshot wounds - 103
Everidge, Major J.: A new method of treatment for suppurative arthritis of the knee-joint - - - - - - - 566
Eversion chain for drop-foot - - - - 517
Excision, limited, for wounds of the elbow-joint 268
— primary, for wounds of the elbow-joint, results of - - - - - - 265
'Explosive' effects on cranium of close-range high-velocity missile - - - 556, 557
Extension in cases of fractured femur at the base, maintenance of - - - - - - 368
— — — — methods of - - - - - 357
— by weight in the treatment of war fractures - - - - - - - - 166
External popliteal nerves, injury of 430, 431, 437, 438, 445, 446, 448, 455
Extraction of foreign bodies in the brain, a new system of - - - - - - - 409
Extravasation of urine as a complication of war injuries of the bladder - - - - - 37

FACE, gunshot wounds of - - - 57, 74, 86
— — — with extensive destruction of lower lip and mandible - 74
— — — early treatment - - - - 74
— — — restoration of lower lip - - - 76
— — — — mandibular function - - 75
— and jaws, injuries to, false trismus resulting from - - - - - - - - 87
— — fractures of the alveolus - - - 87
— — — mandible - - - - - - 86
— — — maxilla - - - - - - 87
— — notes on the principles and results of treatment in 200 cases - - 86
Fæcal fistula and extravasation as complications of war injuries of the bladder - 39
Fagge, C. H.: Bilateral ovarian dermoid cysts simulating renal colic - - - - - 468
Femur, fractured, a method of holding the fragments in difficult cases - - - 458
— — at a base hospital in France, treatment 351
— — — application of splint - - - 360
— — — complications - - - - - 373
— — — condition and treatment of patient on admission - - - - 352
— — — correct position of foot in treatment of - - - - - - 371
— — — covering of the lower limbs in - 372
— — — general anæsthetics in cases of - - 353

PAGE

Femur, fractured, at a base hospital, indications for further operation - - - 354
— — — length of time necessary for firm union 375
— — — maintenance of extension - - 368
— — — materials used for slinging limb in Thomas splint - - - - - 359
— — — methods of extension - - - 357
— — — — suspension - - - - - 363–8
— — — movements of joints during after-treatment - - - - - - 372
— — — prevention of pressure sores - - 371
— — — procedure in operating theatre - 353
— — — removal of bone fragments - - 355
— — — selection of splint - - - - 356
— — — surgical treatment of the wounds and fracture on admission - - - 354
— — — track and steps for initial attempts at walking - - - - - - 376
— — — treatment of spreading sepsis or gas infection - - - - - - 354
— — — — wounds - - - - - 368
— — — use of fracture boards - - - 371
— — — — Sinclair foot-piece - - - 359
— — — vascular gangrene in cases of - - 356
— — — walking caliper splint for - - 375
— — — ward after-treatment - - - 362
— — — *x*-ray examination of - - - 352
— fractures of, treatment in relation to the primary suture of wounds - - - 99
— — ununited, long pegs introduced from the trochanter in cases of - - - 225
— wards - - - - - - - 351, 362
Fergusson, Capt. J. Newbery: A new system of localization and extraction of foreign bodies in the brain: a preliminary note - - - - - - - 409
— Sir William, biographical notes of - - 479
Fibula as a source of bone grafts - - - 233
— and tibia, fractures of, treatment in relation to the primary suture of wounds - - 99
Fistula, fæcal and recto-vesical, as a complication of war injuries of the bladder - 39
Fixation of bone grafts in operative treatment of ununited fractures - - - - 233
Flail elbow after excision - 198, 253, 269, 270
Flannel bandage as sling for limb in Thomas splint - - - - - - - - 359
Flavine in primary and delayed primary suture of gunshot wounds - 97, 98, 103, 111
Foot, correct position of, in treatment of fractured femur - - - - - - 371
Foot-drop, eversion chain for - - - - 517
— shoe splint for - - - - - - 202
Foot-piece, Sinclair's - - - - - - 359
Forearm, fractures of, treatment in relation to the primary suture of wounds - - 101
— — war, extension treatment - - - 174
— and wrist, treatment of disabilities resulting from war wounds - - - - 250
Foreign bodies as a complication of fractured femur - - - - - 374
— — in the brain, a new method of localization and extraction of - - - - 409
— — lodgement of, in gunshot wounds of the spine - - - - - - - - 482
Forty, Capt. A. Alan, Shefford, Capt. A. D., and Munby, Capt. W. Maxwell: Notes on the principles and results of treatment in 200 cases of injuries to the face and jaws - - - - - 86
Fracture boards in treatment of cases of fractured femur - - - - - - 371
— dislocation of upper end of humerus, unusual type of - - - - - - - 466
Fractures of the alveolus - - - 86, 87
— compound, treatment in primary suture of gunshot wounds - 94, 98, 99, 105

PAGE

Fractures of femur (*see* Femur)
— mandible (*see* Mandible; Face; Face and Jaws)
— maxilla - - - - - - - 86, 87
— patellar border, radiography and treatment 465
— — recognition and significance of - 463
— spine (*see* Spine)
— war, causal agent - - - - - - 166
— — nature of injury - - - - - 166
— — treatment by weight extension - - 166
— ununited, causes, incidence, and natural results of - - - - - - - 203
— — due to loss of substance - - - 203
— — — eburnation - - - - - 210
— — — gross displacement - - - - 207
— — — necrosis - - - - - - 206
— — influence of sepsis and mobility in the causation of - - - - - - 211
— — natural course of - - - - - 212
— — non-operative treatment of - - - 214
— — — — deep and percussion massage - 214
— — — — movements - - - - 215
— — — — passive congestion - - - 214
— — operative treatment of - - - - 221
— — — — aiming at callus production without bone suture - - - 215
— — — — by bone grafting (*see also* Bone Grafting) - - - - - 230
— — — — considerations preliminary to - 216
— — — — by intramedullary pegs - - 224
— — — — long pegs introduced from the trochanter into the femur - 225
— — — — plating - - - - - - 221
— — — — special methods of occasional value - - - - - 228
— — — — step-cut operation - - - 223
— — — — table of particulars of 60 cases - 240
— — with special reference to gunshot injuries and the use of bone grafting - - 203
Fraser, Capt. Forbes, etc.: Primary and delayed primary suture of gunshot wounds - - - - - - - 92
Fullerton, Col. Andrew: Observations on bladder injury in warfare; a study of 53 cases - - - - - - - - 24
Functional condition of muscles, etc., to be considered before operating on ununited fractures - - - - - - - 219
— disabilities due to hysterical war contractures - - - - - - - 579
— disability of the limbs, treatment in a special military surgical hospital - - 497
— — — — by team work - - - - 521

Gangrene of the hollow viscera - - 137
— vascular, in cases of fractured femur at the base - - - - - 356
Gas infection as a complication of war injuries of the bladder - - - - - - 38
— — or sepsis, spreading, in cases of fractured femur at the base - - - - - 354
Gastro-jejunal and jejunal ulceration, secondary (*see also* Jejunal Ulceration) - - 390
Genu retrorsum, knee cage for - - - 200
Goodsir and Syme, researches regarding the growth and repair of bones - - - 19
Grafting of bone in the treatment of ununited fractures (*see also* Bone) - - - 230
— — in ununited fractures of the mandible - 65
— nerves in peripheral nerve injury - - 422
Grafts, pedicled, in ununited fractures of the mandible - - - - - - - 70
Groves, Ernest W. Hey: Ununited fractures, with special reference to gunshot injuries and the use of bone grafting - - - 203
Gunshot injury of Meckel's diverticulum 324

PAGE

Gunshot wounds of bladder (*see* Bladder)
— — bones (*see* Bones; Cranium)
— — face (*see* Face; Face and Jaws; Mandible)
— — femur (*see* Femur)
— — jaws (*see* Face; Face and Jaws; Mandible)
— — joints (*see* Joints, and entries under individual joints)
— — mandible (*see* Mandible; Face; Face and Jaws)
— — peripheral nerves (*see* Nerves)
— — spine and spinal cord (*see* Spine and Spinal Cord)
— — delayed primary suture of - 98, 103, 109
— — excision of, use of dyes in distinguishing dead from living tissue in - - 94
— — primary and delayed primary suture of 92, 95, 98, 103
— — — — — — in amputations - - 107
— — — — — — antiseptics in - - 93, 103
— — — — — — bacteriology in relation to 93, 96, 97, 109, 111, 124
— — — — — — culture tests in - - 93
— — — — — — disinfection of skin in - 96
— — — — — — drainage in - - - 93
— — — — — — dressings in - - - 97
— — — — — — indications for - - - 95
— — — — — — influence of the hæmolytic streptococcus 92, 96, 98, 109, 120
— — — — — — interval between wound and operation - - 101
— — — — — — in joint injuries - - 107
— — — — — — massage and movement in 98
— — — — — — mortality - - - 101
— — — — — — operation for excision of wound - - - 93
— — — — — — progress and after-treatment - - 96, 98
— — — — — — statistical summary - 101
— — — — — — sterility of bullet tracks - 111
— — — — — — temperature charts illustrating cases of 100, 102, 104, 105
— — — — — — in treatment of compound fractures 94, 98, 99, 105
— — — — — — *x* rays in - - - 93
— — a review of four years' experience of - 3–6
— — Stokes' swab and tube for taking specimens from for culture - - 93
— — ununited fractures resulting from (*see also* Fractures, Ununited) - - - 203
— — of upper extremity, treatment of disabilities resulting from - - - 248

Hæmatemesis, post-operative, digestion of the œsophagus as a cause of - - 523
Hæmolytic streptococcus, its bearing on primary suture of gunshot wounds 92, 96, 98, 109, 120
Hæmorrhage, fatal, from rupture of spleen caused by septic infarct - - - 467
— secondary, as a complication of fractured femur - - - - - - - - 373
Hall, Capt. Morton E., and Keith, Prof. Arthur: Bones showing the effects of gunshot injuries, in the Army Medical Collection - - - - - - - 537
Hand, treatment of disabilities of resulting from war wounds - - - - - 248
Higgins, Capt. W. R., and Dobson, Lieut.-Col. J. F.: A case of contusion of the axillary artery - - - - - - 15
Hip-joint involvement as a complication of war injuries of the bladder - - - - 38
— late treatment in gunshot wounds of - - 200

PAGE

Humerus, unusual type of fracture dislocation of upper end of - - - - - - 466
— and elbow, fractures of, treatment in relation to the primary suture of wounds - - 99
HURLEY, LIEUT.-COL. VICTOR, and WEEDON, MAJOR S. H.: Treatment of cases of fractured femur at a base hospital in France - - - - - - - - 351
HURST, LT.-COL. ARTHUR F.: War contractures—localized tetanus, reflex disorder, or hysteria - - - - - - - 579
Hysteria as a cause of war contractures 511, 581
Hysterical contractures, changes secondary to deficient circulation - - - - 593
— — — — — — anæsthesia - - - 596
— — — — — — in bones - - - - 598
— — — — — — excessive sweating - - 599
— — — — — — in joints - - - - 595
— — — — — — malnutrition - - - 597
— — — — — — in muscles - - - 595
— — — — — — in nails - - - - 599
— — — — — — œdema - - - - 594
— — diagnosis of - - - - - - 602
— — etiology of - - - - - - 585
— — pathogenesis of - - - - - 582
— — postural length and postural tone in - 600
— — postures caused by, in lower limb - 591
— — — — in trunk - - - - - 593
— — — — in upper limb - - - - 587
— — treatment of - - - - - 603

ILEOSIGMOIDOSTOMY with division of ileum, the distal end being brought out into the wound - - - - - 382
Immobilization in the operative treatment of ununited fractures - - - - 221
— prolonged, in suppurative arthritis of the knee-joint, disadvantages of - - 566
Implantation, double lateral, in peripheral nerve injury - - - - - - 426
Infarct, septic, of spleen causing rupture of spleen, hæmorrhage, and death - - 467
Internal cutaneous nerve, injury of - 437, 439
— — and median nerves, injury of - - 437
— — median, and ulnar nerves, injury of - 439
— lateral ligament of knee, ruptured, operative treatment of - - - - - 377
— popliteal nerve, injury of - - - 430
Intestinal obstruction as a complication of war injuries of the bladder - - - - 39
— — notes on a case of, with comments on bursts of the intestine - - - 135
Intestine, bursts of - - - - - 135, 140
— small, rupture of into mesentery as the result of the indirect violence of a missile 140
Intramedullary pegs in the treatment of ununited fractures - - - - - - 224
— — living, for the fixation of bone grafts - 234
Introduction to Vol. VI. - - - - - 1
Ischæmic contractures and their treatment 250, 251
Izzard's method of macerating bones - - 538

JACONET for slinging limb in Thomas splint - - - - - - - - - 360
Jaw, interarticular fibro-cartilage of, displacement of, and its treatment (*see also* Mandibular Meniscus) - - - - - 385
Jaws, gunshot injuries of (*see* Face; Face and Jaws; Mandible)
Jejunal and gastro-jejunal ulceration, secondary 390
— — — — clinical picture - - - - 397
— — — — details of 3 cases - - 390–2
— — — — etiology - - - - - 393
— — — — list of 165 reported cases - - 399

PAGE

Jejunal and gastro-jejunal ulceration, pathological anatomy - - - - 392
— — — — situation of ulcer - - - 392
— — — — treatment - - - - - 398
Joint stiffness due to deficient circulation in hysterical contractures - - - 595
Joints (*see also* entries under individual joints)
— gunshot wounds of, ankylosis after - - 195
— — — — bony block after - - - - 195
— — — open operations for the late results of 195
— — — primary and delayed primary suture in - - - - - - - 107
— — — scars limiting movement after - 194
— — — Turner splint in - - - - 193
— infection of, as a complication of fractured femur - - - - - - - 373
— large, affections of due to gunshot wounds; their late results and treatment - 190
— manipulation of - - - - - 192
— surgery of nerves and tendons in relation to 256
— of upper extremity, disabilities resulting from war wounds - - - - - 248
JOYCE, BREVET-MAJOR J. L.: A study of a series of peripheral nerve injuries from a surgical aspect - - - - - 418

KAZANJIAN, MAJOR V. H., and BURROWS, CAPT. HAROLD: Treatment of gunshot wounds of the face accompanied by extensive destruction of the lower lip and mandible - - - - - - 74
KEITH, PROF. ARTHUR: Bone growth and bone repair; researches by Ollier of Lyons and Macewen of Glasgow - - - - - 160
— — — — — researches by Syme and Goodsir 19
— and HALL, CAPT. MORTON E.: Bones showing the effects of gunshot injuries, in the Army Medical Collection - - 537
KENNEDY, ROBERT: Some notes on operative procedure in nerve injuries - - - 317
Kidney affection as a complication of war injuries of the bladder - - - - - 38
Knee cage for genu retrorsum - - - - - 200
Knee-joint, gunshot wounds of, primary suture in 107
— late treatment in gunshot wounds of - - 200
— ruptured internal lateral ligament of, operative treatment - - - - - - 377
— suppurative arthritis of, a new method of treatment - - - - - - - 566
— — — active mobilization in - - - 571
— — — — apparatus for - - - 571
— — — character of the synovial fluid in - 567
— — — disadvantages of prolonged immobilization - - - - - - - 566
— — — formation of adequate joint stomata by operation in - - - - - 569
— — — physiological method of treatment 566, 569

LIGAMENT, internal lateral of knee, operative treatment of ruptured - - - - 377
Ligaments, crucial, diagnosis and treatment of injuries to - - - - - - 176
Limbs, functional disability of, team work in treatment of - - - - - - 521
— — — treatment in a special military surgical hospital - - - - - - 497
Lip, lower, extensive destruction of, in gunshot wounds of the face - - - - - 74
— — restoration of - - - - - - 76
LISTON, ROBERT, biographical notes of - - 333
Localization and extraction of foreign bodies in the brain, a new system of - - 403
Localized tetanus as a cause of war contractures 579
Lower limb, cases illustrating treatment of functional disability of - - - - - 514

Lower limb, peripheral nerve lesions of, methods of treatment where suture is inapplicable 291, 454
— — postures due to hysterical contractures - 591
— — war fractures of, extension treatment - 171
Lung complications in war injuries of the bladder - - - - - - - - 39

MACERATED bones showing the effects of gunshot injuries, in the Army Medical Collection (*see also* Cranium) - - - 537
Macerating bones, Izzard's method of - - 538
Macewen and Ollier, researches into bone growth and bone reproduction by- - 160
McMURRAY, CAPT. J. P.: The operative treatment of ruptured internal lateral ligament of the knee - - - - - 377
MAKINS, SIR GEORGE H.: Introduction to Vol. VI - - - - - - - - 1
Malnutrition due to deficient circulation in hysterical contractures - - - 597
Mandible (*see also* Face; Face and Jaws)
— gunshot wounds of - - - 57, 74, 86
— ununited fractures of, bone-grafting in - 64
— — — incidence, causation, and treatment - 57
— — — pedicled bone grafts in - - - 70
— — — plating in - - - - - - 64
— — — wiring in - - - - - - - 64
Mandibular function, restoration in gunshot wounds of face with extensive destruction - - - - - - - - 75
— meniscus, anatomy of - - - 385–7
— — displacement of, method of causation - 386
— — — — reduction - - - - - - 388
— — — operation for - - - - - 389
— — — symptoms of - - - - - 387
— — — and its treatment - - - - 385
Manipulation of joints - - - - - - 192
Massage, deep and percussion, in the treatment of ununited fractures - - - - 214
— and movement in primary suture of gunshot wounds - - - - - - - 98
— in peripheral nerve lesions - - - - 283
Materials used for slinging limb in Thomas splint - - - - - - - - 359
Maxilla, fractures of - - - - - 86, 87
Mechanical treatment in peripheral nerve lesions 283
Meckel's diverticulum, gunshot injury of - 324
Median nerve, functional results of suture of - 290
— — injury of - 249, 299–305, 424–51 *passim*
— — — treatment of disabilities of hand due to - - - - - - - - 249
— and internal cutaneous nerves, injury of - 437
— and ulnar nerves, injury of - - 302–5
— ulnar, and internal cutaneous nerves, injury of - - - - - - - 439
— — and musculospiral nerves, injury of - 443
Medio-tarsal joint, late treatment in gunshot wounds of - - - - - - - 202
Membrane, Baer's, restoration of urethra by means of - - - - - - - - 494
Meninges, spinal, gunshot injuries of - - 491
Meniscus, mandibular, displacement of, and its treatment (*see also* Mandibular Meniscus) - - - - - - - 385
Mesentery, rupture of small intestine into, the result of indirect violence of a missile - 140
Metabolism in shock - - - - - - 403
Metacarpo-phalangeal flexion splint - 504, 506
Mobility, influence of, in the causation of non-union of fractures - - - - - 211
Mobilization, active, in suppurative arthritis of the knee, and apparatus - - - - 571
MOORE, CAPT. A. EISDELL: The results of primary excision for wounds of the elbow-joint - - - - - - - - 265
MORISON, RUTHERFORD: Notes on a case of intestinal obstruction, with comments on bursts of the intestine - - - 135
MORTON, LIEUT. WM. CUTHBERT: The treatment of functional disability of the limbs in a special military surgical hospital - - - - - - - 497
Morton's wrist splint - - - - - - 199
Motor changes in peripheral nerve lesions - 281
— — in recovering nerve lesions - - - 289
Mouth, limitation of opening, due to injuries of the face and jaws - - - - - 87
Movements, rôle of, in the treatment of ununited fractures - - - - - 215
MOWBRAY, CAPT. RALPH M. DE: A case of congenital elevation of the scapula - 146
MUNBY, CAPT. W. MAXWELL, FORTY, CAPT. A. ALAN, and SHEFFORD, CAPT. A. D.: Notes on the principles and results of treatment in 200 cases of injuries to the face and jaws - - - - - - - 86
Muscle changes due to deficient circulation in hysterical contractures - - - - 594
'Muscular anæsthesia of disuse' - - - 512
Musculocutaneous nerve, injury of - - - 444
Musculospiral nerve, functional results of suture of - - - - - - - - 290
— — injury of 249, 256, 305–7, 315, 432, 436, 443, 444, 445, 453
— — — treatment of disabilities of hand due to - - - - - - - - 249
— — cases of suture of - - - - - 315
— median, and ulnar nerves, injury of - - 443
— and ulnar nerves, injury of - - - - 256
Myositis ossificans as a cause of disability of the elbow-joint - - - - - - 255

NAILS, changes in, due to deficient circulation in hysterical contractures - 598, 599
Necrosis as a cause of non-union of fractures - 206
— as a complication of war injuries of the bladder - - - - - - 38, 45
Nerve bulb pain, cause of - - - - - 275
— bulbs, pencils, spindles, drops, triangles 274, 275, 277, 278
— grafting in peripheral nerve injury - - 422
— injury as a complication of fractured femur - - - - - - - - 374
— — some notes on operative procedure in - 317
— stretcher - - - - - - - - 320
— stretching to facilitate meeting of ends after injury - - - - - - - 319
— transplantation in peripheral nerve injury - 422
Nerves, divided, the structure, forms, and conditions of the ends of, with a note on regeneration neuromata - - - 273
— peripheral, injuries of, abstracts of 122 case histories, grouped according to nerve affected - - - - - - - 294
— — — alternative methods of treatment where suture, etc., is inapplicable 291, 453
— — — anterior crural - - - - - 434
— — — brachial plexus - - 308–10, 451–3
— — — 'capsulectomy' in - - - - 442
— — — care of the limb - - - - 282
— — — — — by electrical treatment - - 284
— — — — — massage - - - 283
— — — — — mechanical treatment - - 283
— — — — splints - - - - - 284
— — — — whirlpool baths - - - 283
— — — cases associated with aneurysms and brachial plexus injuries - - 450
— — — causalgia in - - - - - 447
— — — conditions found at operation - - 285
— — — double lateral implantation for - 426

PAGE

Nerves, peripheral, injuries of external popliteal 430, 431, 437, 438, 445, 446, 448, 455
— — — external and internal popliteal - 430
— — — functional results of suture - - 290
— — — general reflections on - - - 456
— — — indications for operation - - 285
— — — — resection - - - - - 286
— — — internal cutaneous - - 437, 439
— — — internal popliteal - - - - 430
— — — internal and external popliteal - - 430
— — — median 249, 299–305, 424–51 *passim*
— — — median and ulnar 302–5, 437, 440, 447, 451
— — — method of examination - - - 280
— — — — — for electrical changes - - 282
— — — — — motor changes - - - 281
— — — — — sensory changes - - - 281
— — — — — trophic changes - - - 281
— — — musculocutaneous - - - - - 444
— — — musculospiral 249, 256, 305–7, 315, 432, 436, 443, 444, 445, 453
— — — nerve transplants for - - - 422
— — — neurolysis in - - - - - - 440
— — — obturator - - - - - - 454
— — — painful lesions - - - 447, 450
— — — posterior interosseous - 308, 422, 444
— — — — — and ulnar - - - - 422
— — — posterior tibial - - 424, 436, 444
— — — recovery from of motor and sensory fibres - - - - - - 288. 289
— — — sciatic - 310–14, 374, 423–50 *passim*
— — — from the surgical standpoint - 279, 418
— — — suture for - - 287, 315, 321, 428
— — — tables of results of treatment in 148 cases - - - - - - 293, 294
— — — tabular classification of cases and operations - - - - - 419
— — — technique of operation for - - 286
— — — — exposure of nerve - - 286
— — — — — protection of suture line - 288
— — — — — relaxation of tension - - 288
— — — — — resection - - - - 287
— — — — — suture - - - - 287, 428
— — — — — testing electrical conduction - 287
— — — ulnar 249, 256, 294–8, 302–5, 422–51 *passim*
— — — — and median 302–5, 437, 440, 447, 451
— — — — and posterior interosseous - - 422
— — — unoperated cases - - - - 454
— suture of - - - - 287, 315, 321, 428
— — special needle for - - - - - 322
Nerves and tendons, surgery of, in relation to joints - - - - - - - - - 256
— war injuries of, disabilities of hand due to - 249
Nervous system, central, in patients dead of shock - - - - - - 405, 406, 408
Net bed, Sinclair's - - - - - - 357
Neurolysis in peripheral nerve injury - - 440
Neuromata, regeneration - - - - - 275
Non-union of fractures (*see* Fractures, Ununited)
— of radius or ulna after gunshot wounds, treatment of - - - - - - - 252

OBSTRUCTION, intestinal, notes on a case of, with comments on bursts of the intestine - - - - - - - 135
Obturator nerve, injury of - - - - - 454
Œdema due to deficient circulation in hysterical contractures - - - - - - - 507
— of the limb as a complication of fractured femur - - - - - - - - 374
Œsophagomalacia - - - - - - - - 523
Œsophagus, digestion of, as a cause of post-operative hæmatemesis - - - - 523
Ogilvie, Lieut. W. H.: Weight extension in the treatment of war fractures - - 166
Ollier and Macewen, researches into bone growth and bone reproduction by - 160

PAGE

Operative treatment of ruptured internal lateral ligament of the knee - - - - 377
— — ununited fractures - - - - - 221
Orthopædic apparatus for peripheral nerve lesions where suture is inapplicable - 291
Osteomyelitis and necrosis as complications of war injuries of the bladder - - 38, 45
Ovarian dermoid cysts, bilateral, simulating renal colic - - - - - - - - 468

PAIN, cause of nerve-bulb - - - - 275
Painful lesions in peripheral nerve injury 447, 450
Palate narrow and high-vaulted in modern British skulls - - - - - - - 555
Passive congestion in the treatment of ununited fractures - - - - - - - - 214
Patellar border, fractures of, radiography and treatment - - - - - - - 465
— — — recognition and significance of - 463
Payne, John E.: A case of torsion of the appendix - - - - - - - - 327
Pedicled grafts in ununited fractures of the mandible - - - - - - - - 70
Pegs, intramedullary, for the fixation of bone grafts - - - - - - - - 234
— — in the treatment of ununited fractures - 224
— introduced from the trochanter in ununited fractures of the femur - - - - 225
Pelvic cellulitis as a complication of war injuries of the bladder - - - - - - 37
Periosteum, rôle of, in bone grafting - - 231
Peripheral nerves (*see* Nerves, Peripheral)
Peritonitis as a complication of war injuries of the bladder - - - - - - - 37
Phenomena of surgical shock, some - - 402
Physiological method of treatment of suppurative arthritis of the knee-joint - 566, 569
Plates, fixation of bone grafts by - - - 237
Plating of ununited fractures - - - - 221
— in ununited fractures of the mandible - 64
Posterior interosseous nerve, injury of 308, 422, 444
— — and ulnar nerves, injury of - - - 422
— tibial nerve, injury of - - 424, 436, 444
Post-operative hæmatemesis, digestion of the œsophagus as a cause of - - - - 523
Postural length and postural tone in hysterical and other contractures - - - - 600
Power, D'Arcy: On cancer of the tongue (Bradshaw Lecture, 1918) - - - 336
Pressure sores in cases of fractured femur, prevention of - - - - - - 371
Primary and delayed primary suture of gunshot wounds (*see also* Gunshot Wounds) 92, 95, 98, 103, 109
— excision for wounds of the elbow-joint, results of - - - - - - - 265
Pringle, J. Hogarth: Displacement of the mandibular meniscus and its treatment 385
— and Teacher, John H.: Digestion of the œsophagus as a cause of post-operative hæmatemesis - - - - 523
Pyorrhœa alveolaris *vel* periodontitis a possible cause of the increase in cancer of the tongue - - - - - - - - 345

RADIOGRAPHY of fractures of the patellar border - - - - - - - - 465
Radio-ulnar joint, late treatment in gunshot wounds of - - - - - - - 199
Radius, treatment of non-unior of - - - 252
Rare or Obscure Cases:—
Bilateral ovarian dermoid cysts simulating renal colic - - - - - - - 468
Congenital abnormality of the wrist - 148

PAGE

Rare or Obscure Cases, *continued* :—
Congenital defect of the thorax, with Sprengel's deformity - - - - 325
Congenital elevation of the scapula (Sprengel's shoulder) - - - - 146
Gunshot injury of Meckel's diverticulum - 324
Septic infarct of spleen, causing rupture of spleen, hæmorrhage, and death - - 467
Subastragaloid dislocation reduced by operation after 7 weeks - - - 144
Torsion of the appendix - - - - 327
Unusual type of fracture dislocation of upper end of humerus - - - - 466
Recto-vesical fistula as a complication of war injuries of the bladder - - - - 39
Reflex disorders as a cause of war contractures 580
Regeneration neuromata - - - - 275
Renal colic simulated by bilateral ovarian dermoid cysts - - - - - 468
Resection in peripheral nerve lesions - 286, 287

Reviews and Notices of Books.

The action of muscles, including muscle rest and muscle re-education (Mackenzie) 330
Artificial limbs (Broca and Ducroquet; ed. Elmslie) - - - - - - 156
Blood-pressure; its clinical applications (Norris) - - - - - - - 155
Blood transfusion, hæmorrhage, and the anæmias (Bernheim) - - - - 329
The breast: its anomalies, its diseases, and their treatment (Deaver and McFarland, assisted by Herman) - - - - 470
Burns and their treatment, including dermatitis from high explosives (Macleod) - 477
Clinical forms of nerve lesions (Athanassio-Benisty; pref. Marie; ed. Buzzard) - 156
Collected papers of the Mayo Clinic, vol. ix, 1917 (ed. Mellish) - - - - 474
Commozione cerebrospinale (Pedrazzini) - 477
Construction of the human body considered in relation to its functions, diseases, and injuries (Davis) - - - - - 476
Equilibrium and vertigo (Jones) - - 606
The fitting-out and administration of a naval hospital ship (Sutton) - - - - 152
Gunshot fractures of the extremities (Blake)- 475
Handbook of operative surgery (Wheeler; intro. Keogh) - - - - - - 150
Laboratory methods of the United States Army (U.S. Medical War Manual No. 6) (various contributors) - - - - 330
Lessons from the enemy (U.S. Medical War Manual, No. 5) (McDill) - - - 478
Local and regional anæsthesia (Allen) - 475
Military surgery (Penhallow) - - - 476
Modern urology: in original contributions by American authors (ed. Cabot) - - 331
Nerves of the human body, with diagrams (Whitaker) - - - - - - 611
The operative treatment of chronic intestinal stasis (Lane) - - - - - 609
Poliomyelitis in all its aspects (Ruhräh and Mayer) - - - - - - - - 152
Précis de Radio-diagnostic Technique et Clinique (Jaugeas; pref. Béclerè) - - 150
Principles of surgical nursing: a guide to modern surgical technique (Warnshuis) - 478
Radiography and radio-electro-therapeutics, vol. ii (Knox) - - - - - - 153
Studies in the anatomy and surgery of the nose and ear (Smith) - - - - - 153
Surgery and diseases of the mouth and jaws (Blair) - - - - - - - 154
Surgery in war (Hull) - - - - - 608
Surgical therapeutics and operative technique (Doyen; trans. Spencer-Browne) - - 473

PAGE

Reviews and Notices of Books, *continued* :—
Surgical treatment: a practical treatise on the therapy of surgical diseases, for the use of practitioners and students of surgery (Warbasse) - - - - - - - 476
A text-book of first-aid and emergency treatment (Burnham) - - - - - 155
Transactions of the Sixth International Dental Congress (ed. Brooks) - - 611
The treatment of fractures, vols. i and ii (Leriche; ed. Burghard) - - - 155
Treatment of infected wounds (Carrel and Dehelly) - - - - - - - 475
The treatment and repair of nerve lesions (Athanassio-Benisty; pref. Marie; ed. Buzzard) - - - - - - - 156
Treatment of war wounds (Keen) - - 478
Tumours of the nervus acusticus and the syndrome of the cerebellopontile angle (Cushing) - - - - - - - 472
War surgery of the abdomen (Wallace) - 328
War surgery from firing line to base (Hughes and Banks) - - - - - - 606
War wounds of the lung: notes on their surgical treatment at the front (Duval) - - 477
Richardson, Major George, and Thorburn, Col. William: The pathology of gunshot wounds of the spine and spinal cord - - - - - - - - - 481
Rupture of small intestine into mesentery, the result of indirect violence of a missile - 140
— of spleen, hæmorrhage, and death caused by septic infarct - - - - - 467
Ruptured internal lateral ligament of knee, operative treatment of - - - - 377

Salmond, Capt. R. W. A.: The recognition and significance of fractures of the patellar border - - - - - - - 463
Scapula, congenital elevation of (Sprengel's shoulder) - - - - - - 146, 325
Scar tissue to be considered before operating on ununited fractures - - - - 218
Scars limiting movement of joints - - 194
Sciatic nerve, functional results of suture of - 290
— — injury of - - 310–14, 374, 423–50 *passim*
— — — as a complication of fractured femur - - - - - 374
Screws, fixation of bone grafts by - - - 237
Secondary hæmorrhage as a complication of fractured femur - - - - - 373
— jejunal and gastro-jejunal ulceration (*see also* Jejunal Ulceration) - - - 390
Sensory changes in peripheral nerve lesions - 281
— — in recovering nerve lesions - - 289
Sepsis as a complication of fractured femur - - - - - - - 373
— or gas infection, spreading, in cases of fractured femur - - - - - 354
— influence of, in the causation of non-union of fractures - - - - - - 211
— latent, to be considered before operating on ununited fractures - - - - 216
— in relation to the extensive operation of primary resection of the elbow-joint - 268
Septic infarct of spleen causing rupture of spleen, hæmorrhage, and death - - 467
Sequestra, formation of, as a complication of fractured femur - - - - - 374
Shefford, Capt. A. D., Forty, Capt. A. Alan, and Munby, Capt. W. Maxwell: Notes on the principles and results of treatment in 200 cases of injuries to the face and jaws - - - - - - - - 86
Shock, surgical, blood-vessels in - - - 404
— — blood volume in - - - - - 404

PAGE

Shock, surgical, central nervous system in patients dead of - - 405, 406, 408
— — nature of - - - - - - - - 402
— — prevention and treatment of - - 406
— — metabolism in - - - - - - 403
— — some phenomena of - - - - - 402
— — suprarenals in - - - - - - 403
— — toxicity of the blood in - - - 403
— — transfusion in - - - - - - 407
Short, A. Rendle: A procedure for avoiding colostomy and colectomy - - - 382
— Some phenomena of surgical shock - 402
Shoulder, Sprengel's - - - - - - 146
— — with congenital defect of the thorax - 325
Shoulder-abduction splint, bandolier - - 196
Shoulder-joint, best position for ankylosis - 255
— late treatment in gunshot wounds of - - 196
— treatment of disabilities resulting from war wounds - - - - - - - 255
Sinclair foot-piece - - - - - - - 359
— net bed - - - - - - - - - 357
Skin disinfection in primary suture of gunshot wounds of - - - - - - - 93
Skull (*see also* Cranium)
— narrowness of palate in modern British - 555
Sling-splint - - - - - - - - 506, 508
Slinging limb in Thomas splint, materials used for - - - - - - - - - 359
Smith, Major S. Alwyn: A case of subastragaloid dislocation reduced by operation after 7 weeks - - - - - - 144
— The diagnosis and treatment of injuries to the crucial ligaments - - - - 176
Soap in primary suture of gunshot wounds - 103
Souttar, Major H. S., and Twining, Capt. E. W.: Injuries to the peripheral nerves from the surgical standpoint - - - 279
Specialism in surgery - - - - - - 6
Spinal cord, gunshot injuries of (*see also* Spine and Spinal Cord) - - - - - 491
— theca, gunshot injuries of - - - - 491
Spine and spinal cord, gunshot wounds of, fracture by direct impact, with complete perforation - - - - - - - 485
— — — — — — — — with retention of missile - - 483
— — — — — fracture by tangential blow - 487
— — — — — injuries to the theca spinalis - 491
— — — — — lodgement of foreign bodies - 482
— — — — — pathology of - - - - 481
Spleen, septic infarct of, causing rupture of spleen, hæmorrhage, and death - - 467
Splint, 'active movement,' for suppurative arthritis of the knee - - - 570, 571
— application of, in cases of fractured femur at the base - - - - - - - - 360
— bandolier shoulder-abduction - - - - 196
— Blake's, for extension treatment of fractures 168, 169
— drop-foot shoe, for ankle - - - - - 202
— for genu retrorsum - - - - - - 200
— jointed poroplastic, for flail elbow - - 198
— long skeleton cock-up sling- - - 506, 508
— malleable shoe, for ankle - - - - 202
— metacarpo-phalangeal flexion - - 504, 506
— Morton's wrist - - - - - - - - 199
— selection of, in cases of fractured femur at the base - - - - - - - - 356
— Thomas, materials used for slinging limb in 359
— Turner, for gunshot wounds of joints - - 193
— walking caliper, for cases of fractured femur 375
Splints in peripheral nerve lesions - - - 284
Split-pins, fixation of bone grafts by - - 238
Sprengel's deformity, with congenital defect of the thorax - - - - - - - 325
— shoulder, a case of - - - - - - 146
Step-cut operation for ununited fractures - 223
Sterility of bullet tracks in gunshot wounds - 111
Stokes, Capt. Adrian, and Tytler, Major W. H.: Report on the bacteriology of wounds - - - - - - - - 111
Stokes' swab and tube for taking specimens for culture in gunshot wounds - - 93
Stomach, acute dilatation of - - - - - 125
— — — etiology - - - - 127
— — — post-mortem appearances - - 130
— — — prognosis and treatment - - 131
— — — symptoms - - - - - 129
Stomata of joint, formation of adequate, in suppurative arthritis of the knee-joint - 569
Streptococcus, hæmolytic, its bearing on primary suture of gunshot wounds 92, 96, 98, 109, 120
Stretching of nerves to facilitate meeting of ends after injury - - - - - 319
Stricture as a complication of war injuries of the bladder - - - - - - - - 45
Subastragaloid dislocation reduced by operation after seven weeks - - - - - 144
Suppurative arthritis of knee-joint, new mode of treatment (*see also* Knee-joint) - 566
Suprarenals, adrenalin content of, in shock - 403
Surgery, military, a review of four years of - 1
— specialism in - - - - - - - - 6
Surgical shock, some phenomena of (*see also* Shock) - - - - - - - - - 402
Suspension, methods of, in cases of fractured femur at the base - - - - 363–8
— modified, by counterweights, for cases of suppurative arthritis of knee 571, 572, 573
Suture for the fixation of bone grafts - - 233
— of musculospiral nerve, 3 cases of - - 315
— in peripheral nerve lesions 287, 315, 321, 426
— — — functional results of - - - 290
— — — special needle for - - - 322
— primary and delayed primary, of gunshot wounds (*see also* Gunshot Wounds) 92, 95, 98, 103, 109
Sweating, excessive, in hysterical contractures 599
Syme and Goodsir, researches regarding the growth and repair of bones - - - 19
Synovial fluid as a natural germicide - - 568
— — character of, in suppurative arthritis of the knee-joint - - - - - - 567
Syphilis and tobacco as possible causes of the increase in cancer of the tongue - - 346

Taylor, Major Gordon: A case of gunshot injury of Meckel's diverticulum 324
Teacher, John H., and Pringle, J. Hogarth: Digestion of the œsophagus as a cause of post-operative hæmatemesis - - - 523
Team work in treatment of cases of functional disability of the limbs - - - - 521
Teeth, caries of, as a possible cause of the increase in cancer of the tongue - - 345
Tendon transplantation in peripheral nerve lesions where suture is inapplicable - 291
Tendons and nerves, surgery of, in relation to joints - - - - - - - - 256
Testicle, abscess of, as a complication of war injuries of the bladder - - - - 45
Tetanus as a complication of fractured femur 374
— localized, as a cause of war contractures - 579
Theca spinalis, gunshot injuries of - - - 491
Thomas splint, materials for slinging limb in - 359
Thorax, congenital defect of, with Sprengel's deformity - - - - - - - 325
Thorburn, Col. William, and Richardson, Major George: The pathology of gunshot wounds of the spine and spinal cord - - - - - - - - 481
Tibia as a source of bone grafts - - - 233

PAGE

Tibia and fibula, fractures of, treatment in relation to the primary suture of wounds - 99
Tobacco and syphilis as possible causes of the increase in cancer of the tongue - - 346
Todd, Alan H. : A case of septic infarct of the spleen, causing rupture of the spleen, hæmorrhage, and death - - - 467
Tongue, cancer of (Bradshaw lecture, 1918) - 336
— — history - - - - - - - 337
— — peculiarities - - - - - - 336
— — possible factors causing the increase in - 344
— — statistics - - - - - - 341
— — zoological distribution - - - - 340
Torsion of the appendix, a case of - - - 327
Toxicity of the blood in shock - - - - 403
Track and steps for initial attempts at walking in cases of fractured femur - - - 376
Transfusion in shock - - - - - - 407
Transplantation in peripheral nerve injury - 422
Trench foot in cases of fractured femur - 356
Trephining, specimens of crania in the War Office Collection showing - - - 550
Trismus, false, resulting from injuries to the face and jaws - - - - - - 87
Trophic changes in peripheral nerve lesions - 281
Trunk postures due to hysterical contractures 593
Turner splint for gunshot wounds of joints - 193
Twining, Capt. E. W., and Souttar, Major H. S. : Injuries of the peripheral nerves from the surgical standpoint - - - 279
Tytler, Major W. H., and Stokes, Capt. Adrian : Report on the bacteriology of wounds - - - - - - - 111

Ulceration, secondary jejunal and gastro-jejunal (*see also* Jejunal Ulceration) - 390
Ulna, treatment of non-union of - - - 252
Ulnar nerve, functional results of suture of - 290
— — injury of 249, 256, 294–8, 302–5, 422–51 *passim*
— — — treatment of disabilities of hand due to - - - - - - 249
— and median nerves, injury of - - - 302–5
— median, and internal cutaneous nerves, injury of - - - - - - - 439
— — and musculo-spiral nerves, injury of - 443
— and musculospiral nerves, injury of - - 256
— and posterior interosseous nerves, injury of 422
Union, firm, of fractured femur, length of time necessary for - - - - - - 375
Ununited fractures of the mandible ; their incidence, causation, and treatment - 57
— — with special reference to gunshot injuries and the use of bone grafting (*see also* Fractures, Ununited) - - 203
Upper limb, cases illustrating treatment of functional disability of - - - 499

PAGE

Upper limb, peripheral nerve lesions of, methods of treatment where suture is inapplicable - - - - - - - 291, 453
— — postures due to hysterical contractures - 587
— — treatment of disabilities resulting from war wounds - - - - - - 248
— — war fractures of, extension treatment - 172
Urethra, restoration of, by means of Baer's membrane - - - - - - - 494
Urine, extravasation of, as a complication of war injuries of the bladder - - - 37

Vertebræ, gunshot injuries of (*see also* Spine and Spinal Cord) - - - - 481
Viscera, hollow, gangrene of - - - - 137

War contractures—localized tetanus, reflex disorder, or hysteria (*see also* Hysterical Contractures) - - - - - - 579
— surgery, a review of four years of - - 1
Ward after-treatment of cases of fractured femur - - - - - - - - 362
Wards for cases of fractured femur - 351, 362
Weedon, Major S. H., and Hurley, Lieut.-Col. Victor : Treatment of cases of fractured femur at a base hospital in France - - - - - - - - 351
Weight extension in the treatment of war fractures - - - - - - - 166
— suspension, modified system of, for cases of suppurative arthritis of the knee 571, 572, 573
Whirlpool baths in peripheral nerve lesions - 283
Williams, Capt. Gwynne : Suture of the musculospiral nerve - - - 315
Wires, fixation of bone grafts by - - - 237
Wiring in ununited fractures of the mandible - 64
Wounds in cases of fractured femur, treatment of - - - - - - - - 368
— gunshot (*see* Gunshot Wounds)
Wright, Garnett : Secondary jejunal and gastro jejunal ulcer - 390
Wrist, congenital abnormality of - - - 148
— and forearm, treatment of disabilities of resulting from war wounds - - - 250
— late treatment in gunshot wounds of - - 199
— splint, Morton's - - - - - - 199
— war fractures of, extension treatment - 174

X-ray examination of fractured femur - 352
— — in primary suture of gunshot wounds 93

Zinc, perforated, for slinging limb in Thomas splint - - - - - - - - 360
Zoological distribution of cancer of the tongue 340

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